MYCOLOGIA

OFFICIAL ORGAN OF THE MYCOLOGICAL SOCIETY OF AMERICA

Vol. XLIV SEPTEMBER-OCTOBER, 1952 No. 5

CONTENTS

[MYCOLOGIA for July-August (44: 431–585) was issued August 2, 1952.]

PUBLISHED BIMONTHLY FOR

THE NEW YORK BOTANICAL GARDEN

AT PRINCE AND LEMON STS., LANCASTER, PA.

Entered as second-class matter April 30, 1925, at the post office at Lancaster, Pa., under the Act of August 24, 1912.

MYCOLOGIA

Published by

THE NEW YORK BOTANICAL GARDEN

IN COLLABORATION WITH THE

MYCOLOGICAL SOCIETY OF AMERICA

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BIOLOGICAL EFFECTS OF IONIZING RADIATIONS FROM RADIUM AND POLONIUM ON CERTAIN FUNGI [1]

SIGMUND BERK

(WITH 7 FIGURES)

A number of natural radioactive elements (radium, radon, polonium, mesothorium, uranium, thorium and actinium) have been used to study their effects on microorganisms. Of the artificially radioactive elements produced by the nuclear reactors, only radiophosphorus (P^{32}), radiocobalt (Co^{60}) and radioiodine (I^{131}) have been widely used on microorganisms. The introduction of radioactive materials (radium and polonium) plated on metallic foils as static eliminators for industrial processes (2) offered a ready means for their application in the prevention of the deterioration of optical instruments due to fungus growth. This investigation was undertaken to determine the effectiveness of the radiations from the radioactive foils in inhibiting fungus growth.

REVIEW OF LITERATURE

The literature on the effect of radioactive materials on microorganisms is voluminous. A great part of this work is concerned

[1] Extract presented at the Meeting of the Society for Industrial Microbiology held in conjunction with the American Association for the Advancement of Science, Philadelphia, Pa., December 27, 1951. Appreciation is expressed to the Ordnance Corps, Department of the Army, for permission to publish this article.

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with the effects of the radiations on bacteria and yeasts. Duggar (**5**) summarizes the work done up to 1935 on the biological effects of radiation. Warren (**16**) more recently reviewed the work of the effect of emanations from radioactive elements on bacteria. The results of the early workers on the effect of radioactive materials on microorganisms ranged from stimulation and acceleration of growth (**10, 11**) to no effect (**13**) and finally to inhibition and lethal action (**3**). Prescott (**13**) irradiated *Saccharomyces cerevisiae* for 20 to 80 minutes at a distance of one cm and found no effect on growth. However, his radium container was shielded with rubber and he was getting only the effects of the beta- and gamma-radiation. Dauphin (**3**) found that radium inhibited the growth of the mycelium of *Mortierella* but did not kill either the mycelium or the spores.

So far as alpha radiation is concerned, Zirkle (**5**) states that no favorable effects have ever been produced from irradiation of cells with these particles. It is now well established that radioactive emanations will produce lethal effects on fungi if the dose is sufficiently great.

MATERIALS

Radioactive Gold Foil. The nucleus of a radium atom ejects three fundamental types of radiations (particles or rays): alpha particles, beta particles and gamma rays. The radium-activated foil used in this investigation was prepared by the US Radium Corporation. A description of this and similar radioactive foils is given by Vicklund (**15**) and Berman and Ernest (**2**). The foil consists of a mixture of radium and barium sulfates and gold powder with a silver backing for mechanical support. The thickness of the foil was about 0.003 inch and contained 15 micrograms (μg) of radium per square inch.

Radium in equilibrium with radium C has four sets of alpha particles per disintegration, one each for radium, radon, radium A, and radium C. The radioactive foil used in this study was in equilibrium with its decay products. One square inch (15 μg) would emit 2.2×10^6 alpha particles per second.

Polonium Foil. The polonium or radium F used was plated on one side of a nickel strip 2.3 × 2.3 cm and had an activity of 11

millicuries (mc). Polonium offers practically a monoenergetic source of alpha particles with a very small amount of weak gamma radiation. A millicurie of polonium emits the same number of alpha particles per second (3.7×10^7) as one milligram of radium freed of its radioactive disintegration products.

PROCEDURE AND RESULTS

Effect of Irradiation with a 7.5 μg Radium Foil on Seven Species of Fungi. Ten cm Petri dishes containing 20 ml of solidified Difco potato-dextrose agar were seeded with 2 ml spore suspensions of each of seven organisms. A strip of the radioactive gold foil 1 in. × 0.5 in. containing 7.5 μg of radium was inserted edgewise into the agar (FIG. 1). All cultures and tests reported herein were incubated in a constant temperature room maintained at 29 ± 1° C., unless indicated otherwise. This test was run in duplicate. All the species of fungi listed in TABLE I had zones of inhibition of

TABLE I

EFFECT OF RADIOACTIVE FOIL (APPROXIMATELY 7.5 μG RADIUM) ON THE INHIBITION OF SEVEN SPECIES OF FUNGI INCUBATED ON POTATO-DEXTROSE AGAR IN PETRI DISHES

	FA No.	No. of days incubated	Zone of inhibition in mm
Rhizopus nigricans ATCC *6204*	54	5	0
Chaetomium globosum	17	7	32 × 57
Lenzites trabea	27	3	32 × 51
Aspergillus niger USDA TC *215–4247*	13	3	30 × 55
A. flavus	9	7	50 × 82
Penicillium sp.	39	7	38 × 70
Monilia crassa	30	5	0

growth and sporulation at the end of the incubation period, except *Rhizopus nigricans* and *Monilia crassa*. The latter two fungi had an uncommon type of aerial growth. The absence of zones of inhibition may be due to the ability of these fungi to bridge the path of the alpha radiation, or more likely to the smallness of the dose.

The effective range of the alpha particles in air from this radium decay system is 4.72 cm (**18**). The largest zone of inhibition was shown by *Aspergillus flavus* but even this fell short of the maxi-

mum range of the alpha-particle system. There is a limit to the size of the zone of inhibition which may be obtained since the range in air of alpha particles from radium varies from 3 to 11 cm. Evans (**6**) lists the maximum range of the alpha particles from

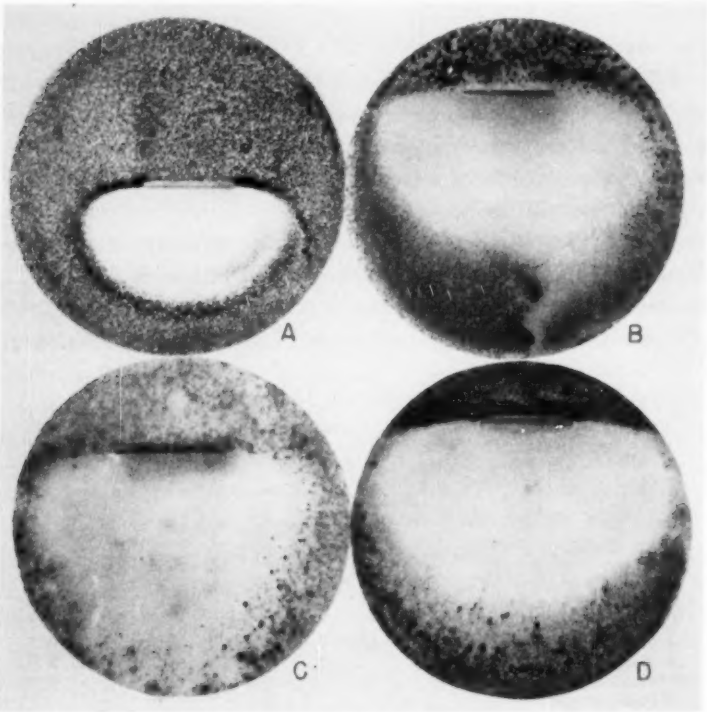


FIG. 1. Zones of inhibition of sporulation and growth of four species of fungi produced by irradiation with a 7.5 microgram radium source. The Petri dishes were seeded with spore suspensions of the following organisms: A—*Aspergillus niger*, B—*Penicillium* sp., C—*Lenzites trabea*, and D—*Aspergillus flavus*.

the radioactive foil ("extended linear sources of radium") as 6.9 cm of air. It is evident that a radium concentration of 15 μg per square inch yields an alpha source which is too weak to exert the maximum effectiveness which could be obtained from the ranges of its alpha particles.

Vicklund (**15**) showed that foils containing 30 μg per square inch produced the same inhibition as that obtained with 15 μg.

It may be concluded from TABLE I that the number of alpha particles required to inhibit growth varies among the different fungi. In other words, the various species of fungi exhibit different radiosensitivities. Tascher (**14**) found that there was a wide range in the tolerance of different species of fungi to irradiation by X-rays. Pearson *et al.* (**12**) exposed 43 fungi to beta radiation from P^{32} and beta and gamma radiation from I^{131} and found that the inhibition of growth varied from species to species. Dimond and Duggar (**4**) irradiated with UV three species of fungi belonging to different genera and found that the three fungi had differences in susceptibility to the radiation.

Type of Radiation from Radium Responsible for Fungus Inhibition. That radioactive emanations from radium (whether alpha, beta, or gamma) inhibit the growth of microorganisms when the dose is great enough is well known. A preliminary experiment was performed to determine the type of radiation from the weak radium source that is primarily responsible for fungus inhibition. Strips of the radioactive gold foil (1.8 μg radium) alone and shielded by aluminum and lead absorbers were inserted edgewise into Petri dishes containing Difco potato-dextrose agar inoculated with *Aspergillus niger* USDA TC *215–4247*.

After seven days' incubation it was found that the plates with the unshielded radioactive gold foil produced a semicircular zone of inhibition (approximately 2×4 cm) of sporulation of *Aspergillus niger*. The plates with the radium foils shielded by aluminum or lead absorbers did not have the zones of inhibition. The beta- and gamma-radiation from this weak radium source had no visible effect on the growth and sporulation of the fungus. The high energy alpha particles from the radioactive gold foil are considered primarily responsible for the prevention of the sporulation of the fungus. This is in agreement with the work of Jacobson *et al.* (**9**) who attributed the biologic effect of radium to the alpha-radiation.

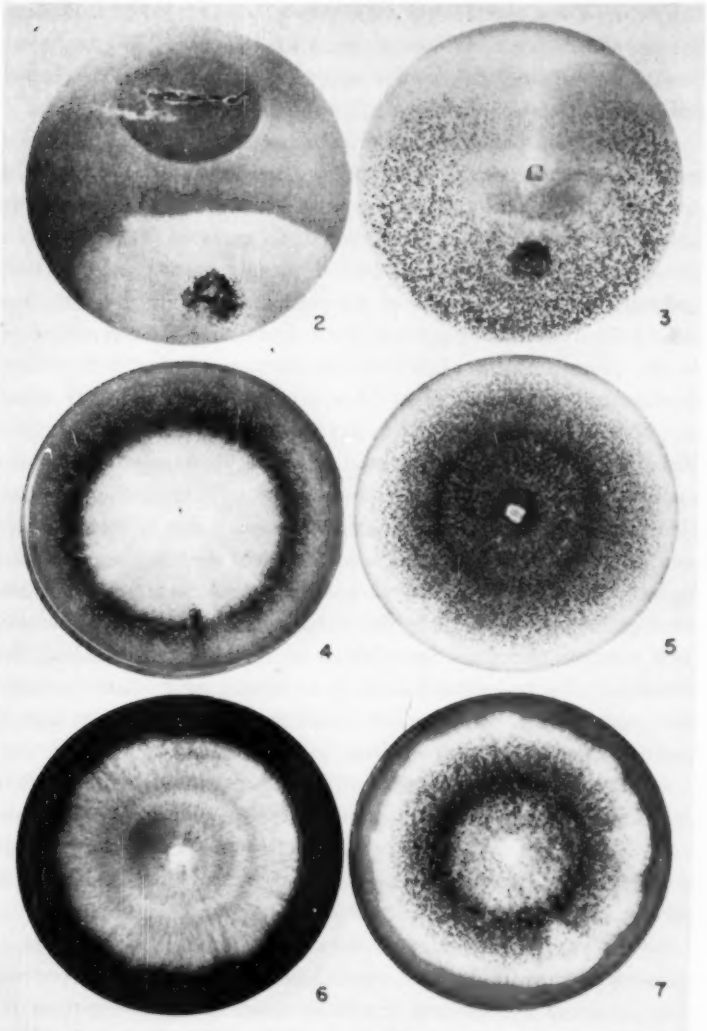
Pearson *et al.* (**12**) exposed *Aspergillus niger* spores for 48 hours to 20 μc sources of radiophosphorus, P^{32} (a pure 1.7 Mev

beta emitter) and radioiodine I^{131} (a beta- and gamma-emitter). No gross morphological changes were observed in the fungus. A decrease in the growth rate was obtained in the spores exposed to the I^{131} and no effect with the P^{32}. Gray and Read (**7**) determined the lethal effect of alpha radiation from the inert gas radon in aqueous solution on bean roots. They also considered the biological effect of the beta and gamma radiation as negligible since the lethal effectiveness of the alpha radiation was ten times as great as the beta and gamma rays.

Effect of Polonium on Aspergillus niger. Petri dish bottoms containing 20 ml of solidified potato-dextrose agar were inoculated with *Aspergillus niger* spores distributed in a slab of potato-dextrose agar. Petri dish tops (2.5 cms deep) containing a slit approximately 2.8×0.2 cm were obtained. The polonium source was inserted into the agar through the slit of the Petri dish top. About 2 mm of the polonium source was inserted into the agar medium. The slab of inoculum (FIG. 2) was about 5 cm from the polonium source. For comparative purposes, a strip of radioactive gold foil (1.2×2.5 cm) containing approximately 7.5 μg of radium was inserted into the agar in a Petri dish.

The plates were irradiated with the polonium and radium sources during the entire 7-day incubation period. FIG. 2 shows the effect of the 11 mc source of polonium. The alpha activity of the polonium was so high that it not only prevented the sporulation of *A. niger* but also inhibited the vegetative growth of the fungus. There was a heavy build-up of spore heads back of the slab of agar used as the inoculum. The slab of agar served as a shield for the alpha radiation. It is possible that the extreme white dense growth of mycelium produced is due to the effect of the high ozone production from the alpha activity. Allen (**1**) reported that when air is irradiated with alpha particles ozone is produced.

From FIG. 2 it is seen that there was no mycelial growth for a distance of 4 cm in front of the foil, and no spore heads for a distance of 4.5–5.0 cm. Since the range of alpha particles from polonium in air is approximately 4.0 cm at 30° C., the effect of the alpha particles on the production of spore heads was present at a distance greater than the range of the alpha particles.



FIGS. 2–7. *Aspergillus niger*. 2. Inhibition of growth produced by a 11 mc polonium source. 3. Dwarf conidial heads produced by a slab of agar exposed to polonium for 7 days. 4. Zone of inhibition of sporulation produced by the external irradiation of the fungus with a 3.7 μg radium source. 5. Growth of the nonirradiated control. 6. Inhibition of sporulation produced by the external irradiation with a 5.3 mc polonium source and 7. with a 3.7 μg radium source.

FIG. 2 shows an elliptical darker zone in the agar surrounding the slit which contained the polonium source. This elliptical zone was probably produced by the polonium flaking from the nickel foil and going into solution in the agar medium.

A number of biological experiments were performed to determine whether the polonium was present in the culture medium. In one test, the polonium source was inserted into solidified sterile potato-dextrose agar in a Petri dish and incubated for seven days. Slabs of the sterile agar were cut out at various distances in front and back of the active side of the polonium source. In FIG. 3 a slab of the irradiated agar about 5 mm in front of the active surface of the polonium was placed on the surface of solidified potato-dextrose agar in a Petri dish. A slab of agar inoculum of *A. niger* was placed at a distance of 2.5 cm from the slab of irradiated agar. FIG. 3 shows that dwarfed conidial heads of *A. niger* were produced for some distance surrounding the irradiated slab of agar. However, slabs of agar taken behind the active side of the polonium sample also produced dwarfed spore heads of the fungus. The biological effect obtained is not completely due to the actual bombardment of the agar medium by the alpha particles from the polonium. The zone of abnormal sporulation of *A. niger* surrounding the location of the transferred slabs of irradiated agar is attributed to the toxic effect of the polonium which had flaked from the sample and dissolved in the agar medium.

Similar biological effects from the insertion of the radioactive gold foils containing 15 μg of radium were not obtained. However, to avoid the possibility of the radioactive materials leaching into the medium experiments were designed so that only the effects of external radiations from the radioactive source were obtained.

Effect of External Radiations on Aspergillus niger. FIG. 4 shows a zone of inhibition of sporulation 5.0 cm in diameter which was produced by constant irradiation from a ½ in. square of the radioactive foil (3.7 μg radium) attached to the inside of a Petri dish cover. The distance from the radium source to the agar surface was 10 mm. This zone of inhibition of spore production is whitish in color, wrinkled, leathery in consistency, and shows deep radial grooves in the central portion. Whelden (**17**) bom-

barded *Aspergillus niger* spores with low voltage cathode rays and grew the irradiated spores on potato-maltose agar. He also obtained a series of radiating ridges and wrinkling of the mycelium.

Examination of the irradiated culture at 20 × magnification revealed the presence of aerial hyphae and surface growth at all points in the "sterile" zone. However, the amount of surface growth increases from the center to the periphery of the "sterile" zone. White immature and abnormal spore heads are present 2 to 3 mm from the periphery. At the periphery (FIG. 4) sparse sporulation is present. Isolations made at the edge of the "sterile" zone often yield mutant strains of the fungus.

The surface of the agar of the central zone of inhibition of sporulation (FIG. 4) is covered with a felt-like mycelial mat which was difficult to puncture even with a platinum needle. Normally, *A. niger* produces sparse fungus tissue with abundant spore heads on this medium (FIG. 5).

Fragments of the aerial structures from the "sterile" zone were removed with forceps and examined under the microscope. The structures did not take the blue stain when a drop of lactophenol containing cotton blue was added. Many of the strands resembled conidiophore initials which were deformed and convoluted. The constant bombardment by alpha particles prevents the formation of normal reproductive structures. As conidiophore initials rise above the surface of the agar, they are killed by the alpha radiation.

To determine whether the surface strands in the "sterile" zone were living or dead, they were transferred to fresh culture medium. Results of all such transfers with few exceptions were negative. However, when pieces of agar containing the leathery rind were cut out and transferred to fresh culture medium, growth of the fungus was obtained. These results would indicate that the surface of the leathery pad is dead tissue and acts as a shield for the living mycelium below the surface.

Effect of Removal of Radioactive Source on Sporulation. A number of experiments were conducted to determine whether the removal of the radioactive source from a continuously irradiated culture would restore the ability of the culture to sporulate in the "sterile" zone. The Petri dish tops containing 3.7 μg of radium

were removed from cultures of *A. niger* that had been growing on the potato-dextrose agar (FIG. 4) for seven days. The cultures were covered with Petri dish tops without any radioactive material and allowed to incubate for an additional 48 hours. There was a heavy build-up of spore heads in the center where the original inoculum was present. Sparse sporulation and radii of spore heads appeared throughout the "sterile" zone. However, it is not known whether these spore heads arose from the old conidiophore initials or from new growth below the surface of the leathery mat of mycelium. Ingber (**8**) irradiated *Actinomyces bovis* with mesothorium, and also found that when the source of radiation was removed, normal growth of the fungus was resumed.

Fungus Inhibition by External Irradiation from a Strong Source of Polonium and a Weak Source of Radium. A strong polonium source (23 × 23 mm) with an activity of approximately 5.3 mc and a weak radium source (12 × 12 mm) of approximately 3.7 μg were placed about 24 mm away from the surface of the solidified potato-dextrose agar in Spray anaerobic dishes. The plates were inoculated with *A. niger* made up in potato-dextrose agar. FIG. 6 shows the inoculum as a white cube in the center of the dishes. After six days' incubation, the diameters of fungus growth were as follows: control, 92 mm; radium plate, 75 mm; and the polonium plate, 65 mm. It is evident from the diameters of growth obtained that alpha radiation is somewhat inhibitory to vegetative fungus growth.

The alpha radiation from the polonium was so great that there was almost 100 per cent inhibition of sporulation (FIG. 6). Only at the periphery of one edge of the culture is there a small patch of spore heads visible (FIG. 6). The concentration of alpha particles bombarding this area was probably too low to prevent sporulation. The plate irradiated with the 3.7 μg of radium had only partial inhibition of sporulation (FIG. 7). However, the strength of the polonium source was much greater than that of the radium source.

SUMMARY

Experiments were conducted on the effects on certain fungi of ionizing radiations from radium and polonium plated on metallic

foils. It was concluded that with the radioactive sources used the alpha particles were primarily responsible for the biological effects observed. Constant irradiation with a 7.5 μg source of radium inhibited the growth and sporulation of *Chaetomium globosum, Lenzites trabea, Aspergillus niger, A. flavus,* and a species of *Penicillium* growing on potato-dextrose agar in Petri dishes. There was an appreciable difference in the radio-sensitivity of the different species of fungi to the ionizing radiation.

A strong polonium source inhibited the vegetative growth and sporulation of *A. niger*. Slabs of agar removed from polonium irradiated culture medium and placed on agar cultures of *A. niger* produced dwarfed conidial heads of the fungus. The zone of inhibition of sporulation produced by the radiation of a culture of *A. niger* is whitish, wrinkled, and leathery in consistency. The surface growth in the "sterile" zone is not viable. Removal of the source of ionizing radiation restores the ability of the culture to sporulate in the "sterile" zone.

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A METHOD FOR VARYING THE AVERAGE NUMBER OF NUCLEI IN THE CONIDIA OF NEUROSPORA CRASSA

CHARLES HUEBSCHMAN [1]

(WITH 1 FIGURE)

When conidia are cut off by the aerial hyphae of *Neurospora crassa* varying numbers of nuclei are included in their cytoplasm. The number is never zero but may range from one to more than thirty with a distribution skewed towards low numbers. The average number of nuclei is, however, rather constant for conidia secured under similar conditions. In experiments on the cause of death of *Neurospora* conidia after ultraviolet treatment it was found that the number of units inactivated was equal to the average number of nuclei present (Atwood and Norman, **1949**; Norman, **1951**). It therefore became desirable to have conidia with different average numbers of nuclei in order to test the hypothesis that nuclear inactivation was the cause of the ultraviolet-induced death of conidia. Among environmental variables that might change the average nuclear number, the composition of the medium on which the conidia were formed proved to have a significant effect.

MATERIAL AND METHODS

Four strains of *Neurospora crassa* were used in these experiments: *1A* is a standard wild-type strain; *5531A* requires pantothenic acid for growth; *26a* requires pantothenic acid, is albino and of the opposite mating type; *4545A* requires lysine for growth. In one instance a heterocaryon between *4545A* and *5531A* was used. The wild type stock and the heterocaryon were maintained at 25° C. on agar slants containing minimal synthetic medium (Ryan, **1950**); slants for the biochemical mutants were supplemented with 0.5% Difco-yeast extract and 0.5% Difco-casamino

[1] Deceased April 25, 1951. Manuscript prepared by Francis J. Ryan.

acids (complete). The conidia to be studied were allowed to form at 25° C. in petri dishes containing either of these two media or media supplemented with other factors as will be described in association with the data.

In preparing slides for study, a cover slip smeared with albumen fixative was either pressed against the conidial mass in the petri dish or a loopful of conidia was patted onto its surface. The cover slips then were immersed in Carnoy's fixing fluid (with or without chloroform) for 25 minutes, followed by hydrolysis in 1N hydrochloric acid at 55–60° C. for from 9 to 14 minutes and staining in a mixture of 50 ml. of 2% aqueous azure A (Flax and Pollister, **1949**), 3 ml. of 10% $NaHSO_4$ and 3 ml. 1N hydrochloric acid for one-half hour. The preparations were then dehydrated and mounted in xylol clarite. Some of the earlier preparations were made by a modification of a method described by DeLamater (**1948**) but the best material was obtained by the above procedure. Upon microscopic observation the nuclei appeared as small intensely staining spheres. In establishing the average nuclear number the contents of more than 500 conidia were counted for each experimental condition.

RESULTS

TABLE I shows the effect of composition of the medium on the average number of nuclei per conidium. The values marked with an asterisk are the average of two determinations. The values ob-

TABLE I

THE EFFECT OF COMPOSITION OF THE MEDIUM ON THE AVERAGE NUMBER OF NUCLEI PER CONIDIUM

Medium	Age in days	Organism				
		1A	5531A	26a	4545A	5531A + 4545A
Minimal	4	2.64	—	—	—	2.60
Complete	3–8	6.15*	5.37	5.03	—	—
0.5% yeast extract	4–9	2.86	2.58	2.73	—	—
1.0% yeast extract	5–6	4.15	3.18	2.83	—	—
0.5% casamino acids	3	2.76	—	—	—	—
1.0% casamino acids	6–7	6.37*	—	—	5.95	—
2.0% casamino acids	6	5.20*	—	—	—	—

tained on minimal medium are indistinguishable from the average of 2.67 obtained for a heterocaryon of a p-aminobenzoicless-morphological with a pantothenicless-albino strain (Atwood and Norman, **1949**) and close to the value of 2.27 obtained for strain *1A* by Norman (**1951**). The overall average on minimal medium is, then, 2.55 nuclei per conidium. On complete medium, however, an average of 5.68 was obtained with a scatter from 5.03 to 6.36. This is a significantly higher value than that for conidia grown on minimal medium. In tests of the separate components of complete medium it can be observed that yeast extract in high concentrations has a slight effect while casamino acids are more potent. It is concluded that the action of the complete medium results from the combined effects of yeast extract and casamino acids.

A preliminary attempt was made to discover the responsible compound or compounds. Calcium pantothenate (18 μg. per ml.), with and without 0.5% casamino acids, was inactive and yielded averages of 2.54 and 2.85 respectively. L-lysine hydrochloride (9 mg. per ml.) and glycine (10 mg. per ml.) seemed to reduce the nuclear number, yielding averages of 1.93 and 2.11. L-glutamic acid (3 mg. per ml.) and L-asparagine (6 mg. per ml.), on the other hand, raised the averages slightly to 3.18 and 3.49 nuclei per conidium. It would appear, therefore, as though the effective substances were at least partly the dicarboxylic amino acids.

With the possible exception of the response to 1% yeast extract, all of the strains tested responded similarly. It may consequently be suggested that the behavior on a given medium is independent of the strain used.

The average number of nuclei was also independent of the age of the culture from which the conidia were obtained. This fact relates to the mechanism whereby greater or lesser numbers of nuclei are included within the conidia. If the greater numbers of nuclei were due to multiplication after the conidia were cut off, a positive correlation of number with time would be expected. A critical test of this notion could be had by plating conidia from a heterocaryon grown on minimal and on complete media onto minimal agar where only conidia containing nuclei from the two components of the heterocaryon would grow. If multiplication within

the conidia had accounted for the nuclear number the proportion of heterocaryotic colonies growing on minimal agar should be independent of the medium on which the conidia had previously grown. On the other hand, the proportion of heterocaryotic conidia should be greater from the complete medium than from minimal if a larger number of nuclei was included at the time the conidia were formed. The latter mechanism would seem to be the responsible one in

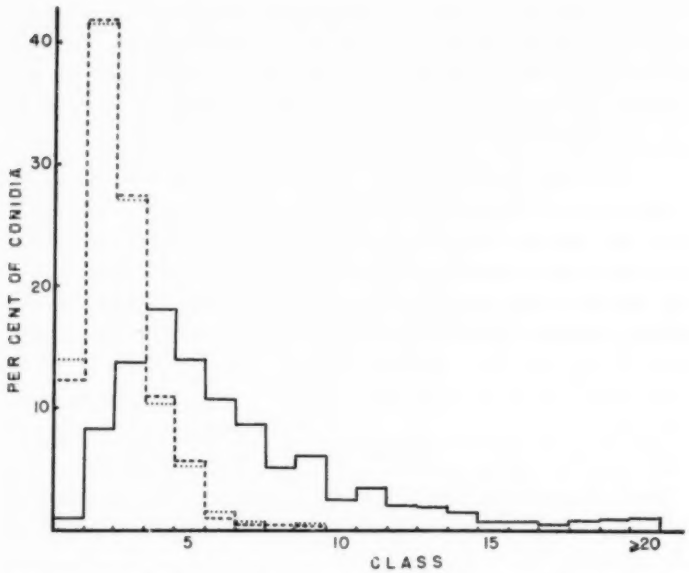

FIG. 1. The distribution of conidia containing different numbers of nuclei. The dashed line is for strain *1A* grown on minimal medium and the solid line for strain *1A* grown on complete medium. The dotted lines are for the heterocaryon *5531A* + *4545A* grown on minimal medium.

view of the fact that the average conidial diameter was 7.1 μ when the average nuclear number was 2.86 and 9.7 μ when the average was 5.94 nuclei per conidium. The conidial volumes differ by a factor of approximately 2 and the nuclear-cytoplasmic ratio is, therefore, probably constant. FIG. 1 shows the effect of minimal and complete medium on the distributions of nuclei among conidia formed by strain *1A*. The distribution in conidia from the hetero-

caryon of *5531A + 4545A* grown on minimal medium is also shown to indicate the precision with which distributions are approximated when conidia are formed on the same medium. Neither of the distributions is Poisson in form.

Conidia with high and low average numbers of nuclei have been prepared by the methods described above and, together with uninucleate microconidia, subjected to ultraviolet light (Norman, **1952**). The killing curves indicated a number of targets corresponding to the average number of nuclei present. However, the sensitivities of the multinucleate conidia were less than that of the uninucleate conidia. The elimination of other possibilities indicated that nuclear interaction was responsible. Furthermore, it has been shown that heterocaryons are recovered in high frequencies after irradiations which, on the nuclear inactivation hypothesis, should have resulted in the survival of a small fractional average number of nuclei per conidium (Atwood, unpublished). It would appear, therefore, that in multinucleate conidia, possessing at least one surviving nucleus, some repair of inactivated nuclei is possible. Viable conidia upon germination contain nuclei which are large, oval and faintly staining except for the terminally located body. Ungerminated (yet still viable) conidia, on the other hand, contain small intensely staining spherical nuclei. Only very rarely have conidia been observed to contain a mixture of the two types. It might be possible, by the use of this cytological criterion, to secure evidence, in irradiated material, on the validity of the hypothesis of the repair of inactivated nuclei.

SUMMARY

The average number of nuclei per conidium can be increased from a value of approximately 2.6 on minimal medium to approximately 6.2 on complete medium. The conidia on complete medium have a volume that is increased approximately in proportion to the increase in number of nuclei. The responsible factors appear to be, at least in part, dicarboxylic amino acids.

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THE NUTRIENT REQUIREMENTS OF AGARICUS CAMPESTRIS GROWN IN SUBMERGED CULTURE

HARRY HUMFELD AND T. FRANK SUGIHARA[1]

(WITH 6 FIGURES)

In a previous paper Humfeld and Sugihara (**1949**) described a process for the production of edible mycelium of *Agaricus campestris*, a mushroom grown commercially in the United States. Briefly, certain strains of *A. campestris* were grown in propagators, equipped for agitation and aeration, and supplied with a medium containing a source of energy (soluble carbohydrate), a source of nitrogen (ammonia, urea, amino acids, or some of the more complex forms of organic nitrogen), and definite concentrations of various mineral elements. The carbohydrates which have been found suitable include glucose, *d*-galactose, *d*-mannose, *d*-fructose, maltose, *d*-xylose, *d*-arabinose, dextrin, mannitol, sucrose, and soluble starch. Lactose, *l*-rhamnose, and sodium carboxymethylcellulose are not utilized. All strains able to grow submerged did not show any increased growth when a mixture of twelve vitamins was added to an agar medium of the same basal composition as the liquid culture.

The data reported below were obtained from quantitative studies in shake cultures of the requirements for nitrogen, phosphorus, potassium, sulfur, magnesium, iron, and zinc.

PROCEDURE

The nitrogen-free basal medium, unless otherwise stated, was as follows:

[1] Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture. Report of a study made under the Research and Marketing Act of 1946. Presented June 21, 1951, Los Angeles, Calif., at a joint session of Northern California–Hawaii and Southern California branches of Society of American Bacteriologists, held in connection with a general meeting sponsored by Pacific Div. of American Association for the Advancement of Science.

	Compound, g./liter	Resulting concentration, mg./liter
Glucose	50	
KH_2PO_4	0.87	K 250, P 150
$MgHPO_4$	0.40	Mg 40, P 100
$CaCl_2 \cdot 2H_2O$	0.37	Ca 100
$H_2SO_4(2N)$	5.1 ml.	S 200
Trace element solution*	20 ml.	Fe 4, Mn 4, Zn 2, Cu 0.5

* The trace element solution was made up as follows: $FeCl_2 \cdot 6H_2O$, 0.5 g.; $MnCl_2 \cdot 4H_2O$, 0.36 g.; $ZnCl_2$, 0.20 g.; and $CuSO_4$, 0.05 g.; water to make one liter.

The basal medium, without the element to be studied, was divided into equal portions; the required amounts of the element to be varied were added to each; each was adjusted to pH 4.5; and 50-ml. amounts were distributed into 250-ml. Erlenmeyer flasks and sterilized at 15 pounds of steam pressure for 20 minutes. The required amount of urea solution sterilized by Seitz filtration was added to each flask to give a concentration of 1500 mg. per liter of nitrogen, except in the study of nitrogen requirement.

Agaricus campestris (strain M_5) was inoculated from agar slants into flasks of the complete medium and incubated on a rotary shaker (125 rpm.; 1–2 cm. radius) at 25° C. until approximately maximum growth was attained. The mycelial growth was centrifuged, washed and resuspended in distilled water by aseptic technique. Two drops of the suspension were added to each flask in the experiment and the flasks were incubated as for the production of the inoculum. For studies of the trace elements, the inoculum was grown on a basal medium lacking trace elements. This avoided a carryover of a sufficient amount of the trace element to allow excessive growth in the series lacking the particular element being studied.

At regular intervals during the incubation period, flasks of each series were removed for analysis. For yield data, the mycelium was separated by centrifuging, washed with distilled water, recentrifuged and dried in weighing dishes in a forced-draft oven at 50° C. Measurements of pH and refractive index were made on the culture medium. For the nitrogen series, glucose also was determined. The amount of the element under study remaining in the centrifuged culture medium was determined in many cases.

Nitrogen was determined by the Kjeldahl-Gunning-Arnold

method; total phosphorus as phosphomolybdate after oxidation with perchlorate; potassium gravimetrically as cobaltinitrite; total sulfur as barium sulfate after oxidation with potassium permanganate; magnesium by spectrographic analysis, calibrated with media containing known amounts of magnesium and calcium salts; glucose by the micro copper reduction method.

The mushroom-like flavor was judged on centrifuged, washed, unsalted mycelium, which was cooked for about one-half hour in flowing steam. The tasting was done routinely by the authors and samples were rated as bland, weak, moderate, and good. No attempt was made to develop a trained taste panel.

At concentrations above 5 per cent of sugar, the incubation time required to utilize all of the sugar was approximately proportional to the increase in concentration, and there seemed to be no advantage in using concentrations above 5 per cent. The study was made in shake culture to simulate larger-scale propagation and to facilitate representative sampling. Production of the mycelium in propagators under agitation and aeration gave a high rate of growth, but the difficulties in obtaining representative samples outweighed the advantages of the greater growth rate.

For convenience, data for concentrations of the various elements which gave similar responses were averaged as indicated in the figures.

NITROGEN

Urea was chosen as the source of nitrogen, because its utilization does not change the pH of the medium sufficiently to have an unfavorable effect on growth. Also, when utilized, it does not leave any residual radical in solution.

The nitrogen requirement for maximal growth is about 1000 mg. per liter (FIG. 1). Larger amounts, up to 3500 mg. per liter, gave no significant increase in yield. The greatest weight of mycelium was obtained after two to three days' incubation. After that, some decrease took place, probably due to autolysis. During the latter phase, the flavor developed, provided a high enough concentration of nitrogen was present. At least 1500 to 2000 mg. per liter in the original medium were required for the development of good aroma and good flavor intensity.

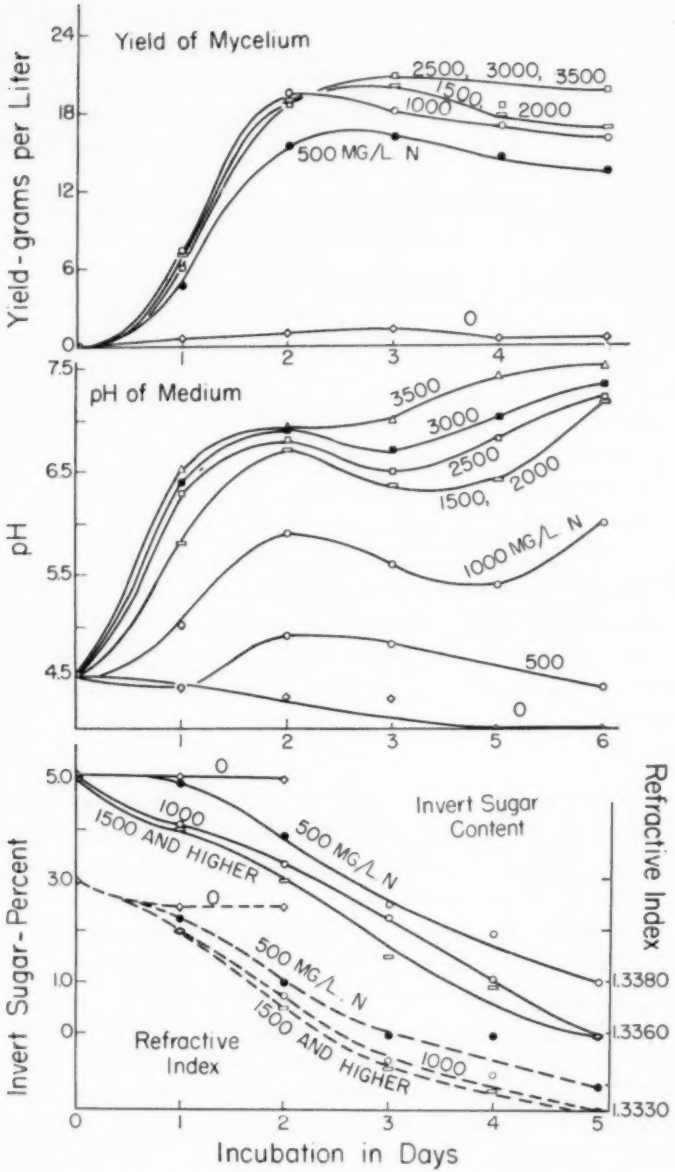

FIG. 1. Effect of nitrogen concentration on yield of mycelium, pH, refractive index, and invert sugar content of the medium.

Apparently the pH of the culture is affected by the rate of change of urea to ammonia and the rate of ammonia utilization.[2] In the later stages, while the yield of mycelium is declining, autolysis also may contribute to the rise in pH. At nitrogen concentrations of 1000 mg. per liter and greater, the pH rose rapidly for the first two days and then decreased gradually. After four to five days, the pH again increased when sufficient nitrogen was present to enable the mycelium to utilize all of the sugar (FIG. 1).

The refractive index was found to be correlated closely with the residual sugar content (FIG. 1) and was substituted for sugar analyses in subsequent experiments.

TABLE I

EFFECT OF CONCENTRATION OF NITROGEN ON NITROGEN CONTENT OF MYCELIUM

Initial nitrogen concentration (mg./liter)	Total N after indicated days of incubation				
	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
0	—	—	2.0	2.0	2.3
500	2.2	3.3	3.0	3.1	3.2
1000	2.0	4.4	5.3	5.7	5.2
1500	2.5	5.2	6.0	6.8	6.2
2000	3.5	5.5	6.2	6.2	6.4
2500	4.0	6.3	6.4	6.5	6.4
3000	3.4	6.4	6.6	6.7	6.4
3500	4.6	6.0	6.9	6.6	6.9

The nitrogen content of the dried mycelium was affected markedly by the amount of nitrogen in the medium (TABLE I). When no nitrogen was added, except for a minute amount carried in the inoculum and as impurities, the nitrogen content was about 2 per cent, while it increased to 6.9 per cent at the highest concentration. If the conventional factor of 6.25 for converting nitrogen content to protein is used, the minimum and maximum correspond to 12.5 and 43 per cent of crude protein, respectively.

PHOSPHORUS

The inorganic constituents of the basal medium were modified as follows (mg. per liter): KCl to give 100 of K; H_2SO_4 to give 200

[2] Urease activity was demonstrated in agar slant cultures by the phenol red test.

of S; $MgCl_2$ to give 5 of Mg; $FeCl_3$ to give 2 of Fe; and $ZnCl_2$ to give 2 of Zn. After addition of various amounts of phosphoric acid (85 per cent), the media were adjusted to pH 4.5 with 10 *N* NaOH, distributed in Erlenmeyer flasks, sterilized, and inoculated.

Maximum yields of mycelium were obtained at concentrations of 50 mg./liter of phosphorus and higher (FIG. 2) after four days of incubation. The small variations at the higher concentrations are probably within experimental error. However, the phosphorus requirement for flavor development is much higher. After four days' incubation, good flavor was present at phosphorus concen-

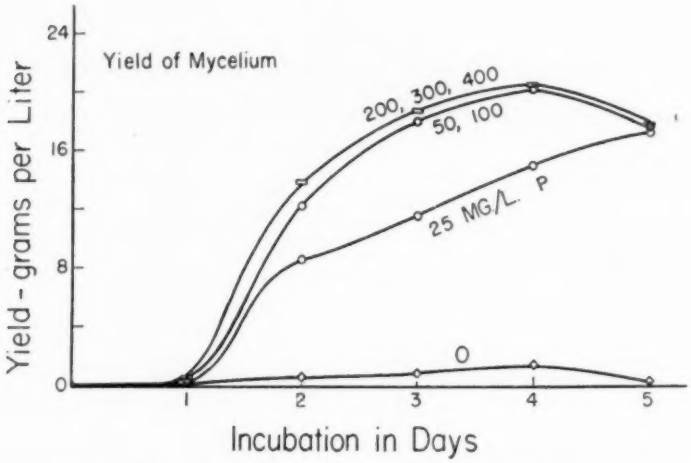

FIG. 2. Effect of phosphorus concentration on yield of mycelium.

trations of 300 and 400 mg./liter, while at five days good flavor was obtained with 200 mg./liter.

There was, as in the case of the nitrogen requirement, a sharp rise in pH in the initial growth stages, followed by a drop at the time of greatest rate of growth and then subsequently a sharp rise at conclusion of the incubation time. The refractive index dropped rapidly for all levels of phosphorus sufficient to give maximum rate of growth. By four days the refractive index had reached its lowest level for all phosphorus concentrations of 50 mg./liter and over, indicating complete assimilation of the sugar.

Practically no phosphorus remained in the culture liquid at any of the concentrations. Apparently it was absorbed by the mycelium after as short a time as one day, and the phosphorus did not appear again, even when growth and flavor development were complete.

POTASSIUM

The inorganic constituents of the basal medium were modified as follows (mg. per liter): $MgHPO_4$ to give 40 of Mg and 50 of P; $CaCl_2 \cdot 2H_2O$ to give 100 of Ca; H_3PO_4 to give 200 of P; and H_2SO_4 to give 200 of S. Various concentrations of KOH were added prior to pH adjustment.

The requirement for potassium is about 100 mg./liter (FIG. 3). In the absence of added potassium the weight of mycelium reached about 10 per cent of maximum growth. Flavor development was good at 300 mg./liter in four days, at 200 mg./liter in five, and at 100 mg./liter in six days. Thus at the minimal optimal level of potassium for growth, flavor development is retarded but eventually reaches a satisfactory intensity.

The pH in general followed the course indicated in the nitrogen and phosphorus requirement studies. There was an indication that the higher the concentration of potassium, the greater was the final pH rise. The refractive index curves were practically identical with those for phosphorus.

Interesting data on potassium assimilation are shown in FIG. 3. The potassium was removed quantitatively (up to 350 mg./liter) from the medium within 2 days, but began to reappear at the fourth to fifth day. At seven days most of the potassium had been liberated from the mycelium.

SULFUR

The inorganic constituents of the basal medium were modified as follows (mg. per liter): $MgHPO_4$ to give 40 of Mg and 50 of P; KH_2PO_4 to give 250 of K and 100 of P; H_3PO_4 to give 100 of P; and $CaCl_2 \cdot 2H_2O$ to give 100 of Ca. H_2SO_4 was added prior to pH adjustment to give various concentrations of sulfur.

Although 50 mg./liter of sulfur was sufficient for maximum yield (FIG. 4), 200 mg./liter was required to obtain a good flavor

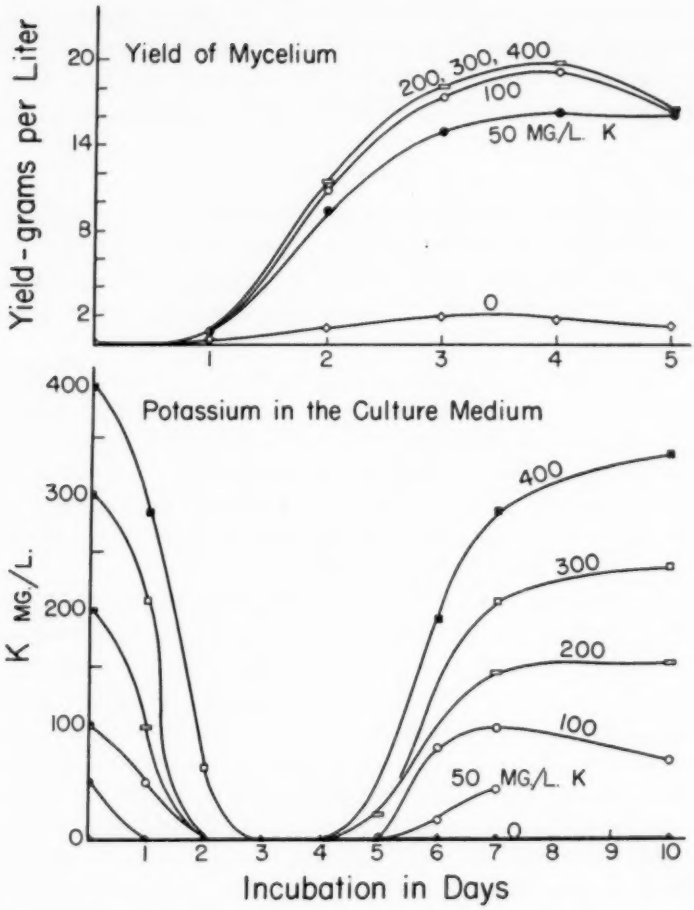

FIG. 3. Effect of potassium concentration on yield of mycelium, and on absorption by and subsequent excretion of potassium from the mycelium.

when tested at 8 days' incubation. The pH followed a course similar to that for other nutrient elements but more consistently upwards. The refractive index followed the usual course. About 150 mg./liter of sulfur was taken up by the mycelium during and after growth, but all except about 50 mg./liter reappeared in the medium after 7 days (FIG. 4).

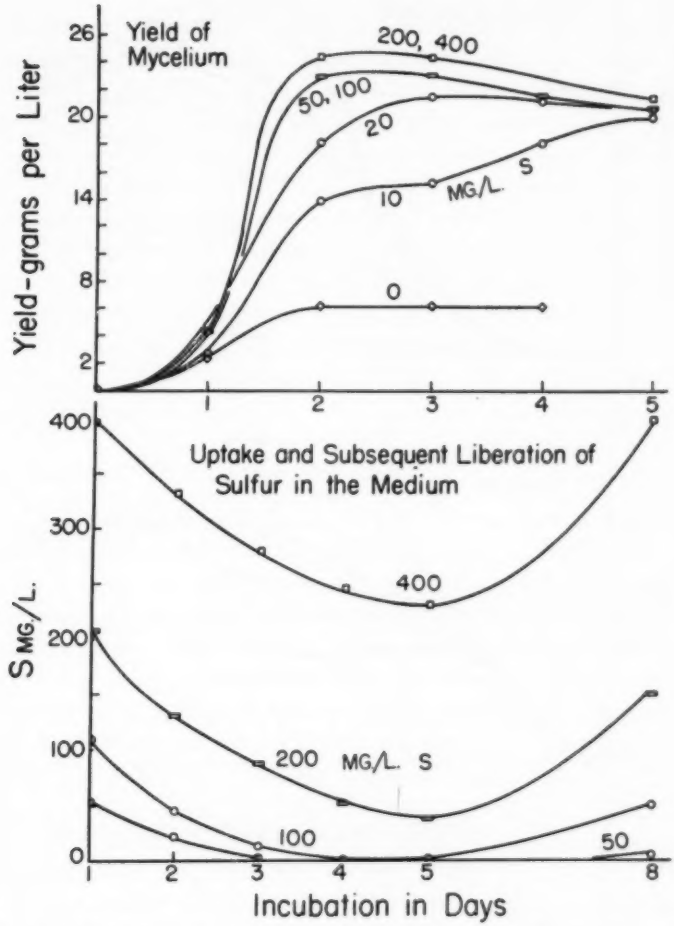

FIG. 4. Effect of sulfur concentration on yield of mycelium and on the absorption by and subsequent excretion of sulfur by the mycelium.

MAGNESIUM

The basal medium was modified as follows (mg. per liter): KH_2PO_4 to give 200 of K; H_3PO_4 to give 300 of P; H_2SO_4 to give 200 of S; $FeCl_3$ to give 4 of Fe; and $ZnCl_2$ to give 4 of Zn.

The highest yield was obtained at 3 days with 20 mg./liter of

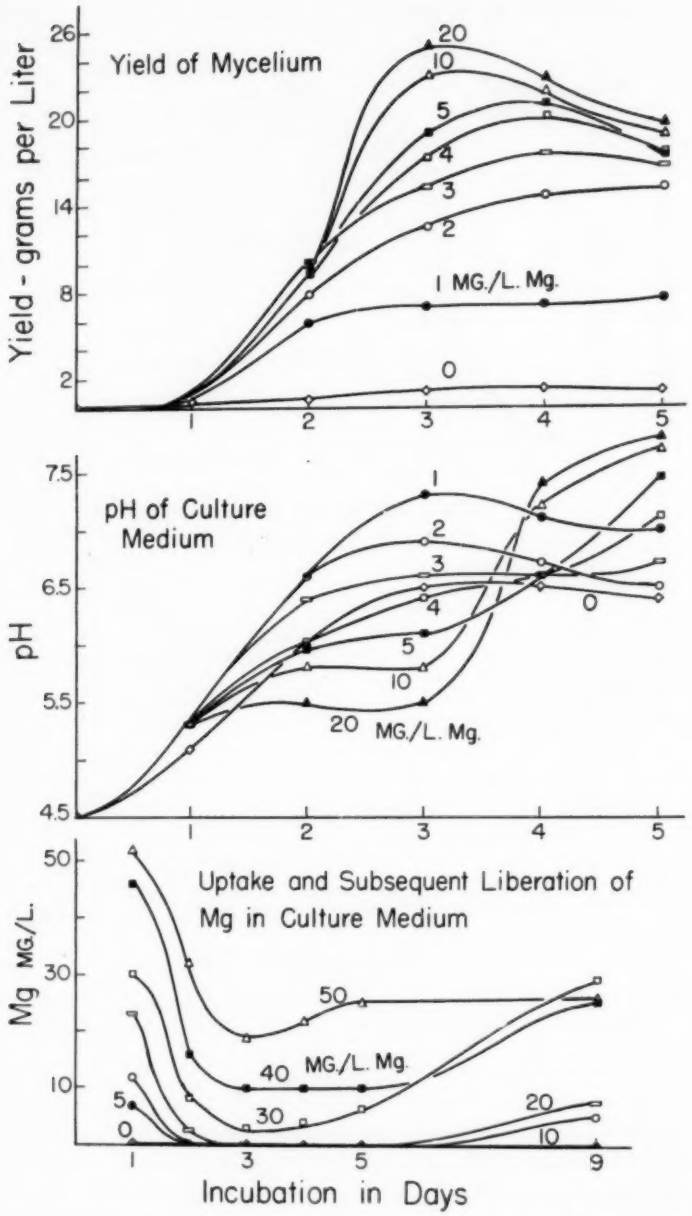

FIG. 5. Effect of magnesium concentration on yield of mycelium, on pH, and on absorption by and the subsequent excretion of magnesium by the mycelium.

magnesium (FIG. 5). A definite loss in weight occurred with longer time of incubation. Good flavor was found by the fourth day at 5 mg./liter and higher concentrations of magnesium. Apparently the development of flavor does not require a higher concentration of magnesium than is required for maximum growth.

The pH increased least during the first three days in those cultures which showed the greater rates of growth and sugar utilization (as indicated by the drop in refractive index). After full growth had been obtained, the reverse became true and the pH increased most for the higher magnesium concentrations.

In a separate experiment, the initial uptake of magnesium was followed by subsequent liberation of all to 20 mg./liter into the culture medium (FIG. 5).

TRACE ELEMENTS

Double-strength basal medium (with 10 mg./liter of calcium) was prepared with redistilled water, adjusted to pH 6.1, and extracted overnight with shaking in glass-stoppered flasks with 0.2 volume of 0.1 per cent 8-hydroxyquinoline in chloroform (Waring and Werkman (**1942**)). After removal of the chloroform fraction, the water phase was then extracted five times with 0.07 volume aliquots of chloroform to remove excess reagent, and adjusted to pH 4.5. The trace elements (Fe, Mn, Zn, Cu, and 1 mg./liter of Co) were added. The flasks were sterilized, urea added, inoculated, and incubated. Depleted inoculum was grown on the extracted medium without addition of the trace element under consideration.

A satisfactory yield was not obtained when either iron or zinc was omitted from the medium. Slightly higher yields were obtained if either manganese, copper, or cobalt was omitted, compared with the presence of all five trace elements.

When calcium was omitted, without any attempts to remove the small amounts which might be present in the other salts used, no decrease in yield was noted.

The magnitudes of the iron and zinc requirements were established by further experiments on extracted media. A maximum yield of mycelium was produced with as little as 0.1 mg./liter of

iron (FIG. 6). More rapid growth was found with 0.2 to 0.6 mg./liter of iron. Flavor was tested at the fifth day. At least 0.6 mg./liter of iron was required to develop flavor and good flavor was found when 2 mg./liter were added. Later tests with higher concentrations of iron did not show further change in the intensity

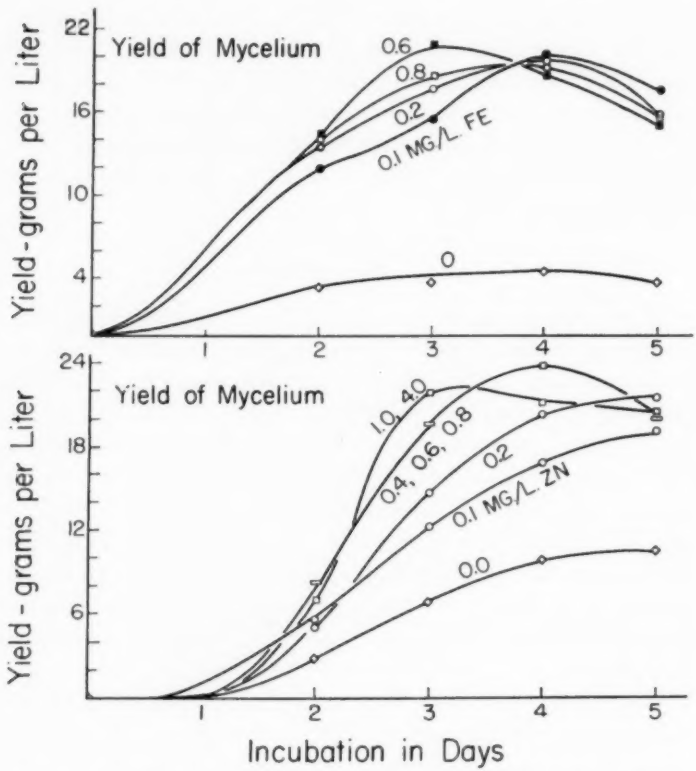

FIG. 6. Effect of concentration of iron and of zinc on yield of mycelium.

of flavor. The higher the concentration of iron (up to 20 mg./liter was tested), the darker brown was the color of the mature mycelium.

Iron was tested in concentrations as high as 640 mg./liter. At concentrations of 80 mg./liter some initial inhibition took place,

but eventually full growth was obtained with the highest concentration tested.

Maximum yields were obtained with 0.2 mg./liter of zinc, but 0.4 to 1 mg./liter gave faster growth (FIG. 6). At 5 days the strongest flavor was obtained with 2 mg./liter of zinc, the highest concentration used. In subsequent experiments with 1, 2, 4, 6, 8, 10, 15, and 20 mg./liter of zinc, there was no increase of flavor with more than 2 mg./liter of zinc, and the mycelium yield was approximately the same throughout.

The effect of copper in the medium was tested on concentrations up to 170 mg./liter. At the higher concentrations of copper the medium had a definite bluish-green tinge. At these levels growth was retarded. Pellet formation occurred, and these pellets became bluish-green, indicating absorption of the copper from solution. After this, normal diffused growth occurred with normal yields of mycelium.

DISCUSSION

The efficiency of a medium for the production of mushroom mycelium may be calculated on the basis of mycelium produced from amount of sugar consumed, as is commonly done with other microorganisms. In the experiments reported here, the maximum yields, when each element had been eliminated as a limiting factor, were 40 to 50 grams of mycelium, calculated to a dry basis, per 100 grams of sugar in the original medium. If the sugar content of a medium is known, one may calculate the amount of nitrogen and the amounts of the other essential mineral elements required to produce maximum yields. Media fulfilling these nutrient requirements have been used successfully in the production of mushroom mycelium in laboratory and pilot plant propagators and have given yields comparable to those obtained in shake flask culture.

Although the data reported here were obtained with strain M_5, good yields and flavor were obtained when this medium was used for the production of mycelium of strains M_{16} and M_{28}. Of some fifty cultures isolated from commercially produced mushrooms of this species, only these three strains were able to adapt themselves to shake flask growth. The others failed to grow or grew only

slowly and with pellet formation. The hyphae of the M_5, M_{16}, and M_{28} strains grown on slants are much more slender and elongated than the hyphae of the other isolates. In liquid culture the M_5, M_{16}, and M_{28} strains produce a greater number of elliptical bodies, apparently asexual spores, such as were described by Kligman (**1942**) as occurring on old agar slants. The M_5 and M_{16} strains were tested and were found to be unable to establish themselves in beds of compost for the production of mushrooms by the usual commercial technique (unpublished data of the authors).

However, under submerged propagation in media containing the proper constituents in the proper concentrations, these strains do produce mycelium with mushroom-like flavor.

TABLE II

CONCENTRATIONS OF ELEMENTS REQUIRED FOR MAXIMUM YIELD AND FOR GOOD FLAVOR

Element	Yield (mg./liter)	Flavor (mg./liter)	Inhibition of growth (mg./liter)
Nitrogen	1000	1500–2000	>3500
Phosphorus	50	300–400	>400
Potassium	100	200–300	>400
Sulfur	50	200	>400
Magnesium	20	20	>50
Iron	0.1	2	>80
Zinc	0.4	2	>20

Daily tests showed that the flavor of the mycelium remains bland until maximum mycelial growth has occurred and the sugar has been completely assimilated. Further incubation then allows development of mushroom-like flavor, provided the higher concentrations of inorganic nutrients required (except for magnesium) are supplied. In the cases of potassium and phosphorus, higher concentrations were also observed to increase the rate of flavor development. Although the authors and their associates and representatives of several food concerns regard the mycelium as having a suitable mushroom flavor, the flavor is designated as "mushroom-like" pending more extensive tests.

The minimum concentrations of each element required for maximum yields and the concentrations which gave a rapid development of flavor are given in TABLE II.

The rapid uptake by the mycelium of certain elements in the culture medium and their subsequent release is noteworthy. Phosphorus is taken completely out of solution in one day, although at this time not more than 5 per cent of the maximum growth would have occurred. Apparently this amount of mycelium contains enough phosphorus to produce maximum yield of mycelium and good mushroom-like flavor. Although potassium, sulfur, and magnesium are assimilated in relatively high concentrations by the rapidly metabolizing mycelium, the greater proportions of these elements are not fixed structurally in the mycelium.

Nutrient requirement studies on growth of mushroom mycelium in submerged culture have not been reported previously in the literature. Studies on the nutrition of the mycelium of the cultivated mushroom in liquid culture has been reported by Treschow (**1944**). In these studies a mycelial mat was produced by carefully floating a section of mycelium grown on agar on the surface of the liquid. Mycelial yields were determined after growth of 30 days' duration or more. Close comparisons of these data with our results are not warranted, since the growth was much slower and the yields much smaller than those obtained by us in submerged culture. Moreover, Treschow worked with fertile strains of mycelium. It is obvious that further studies with fertile strains, rapid growth rates, and high mycelial yields might have important bearing on practical mushroom culture.

SUMMARY

The nutrient requirements for the growth of *Agaricus campestris* mycelium in shake flasks were determined in a 5 per cent glucose medium with urea as a nitrogen source. For maximum flavor development, as well as for good yield of mycelium, these are as follows (in mg. per liter): nitrogen 1500 to 2000, phosphorus 300 to 400, potassium 100 to 300, sulfur 200, magnesium 20, iron 2, and zinc 2. For maximum yield without regard to flavor (in mg. per liter), nitrogen 1000, phosphorus 50, potassium 100, sulfur 50, magnesium 20, iron 0.1, and zinc 0.4 suffice. Except for magnesium the amounts required for maximum yield alone are lower than the requirements for production of good mushroom-like flavor.

The nitrogen content of the mycelium is markedly affected by the amount of nitrogen available in the medium (range 2.0 to 6.9 per cent). Phosphorus is taken up greatly in excess of the amounts required for maximum growth and is not again liberated into the medium. Although potassium, sulfur, and magnesium also are taken up in excess of the amounts required for growth, considerable portions of these elements appear later in the culture medium. Media based on these studies have been used successfully in laboratory and pilot-plant propagators.

ACKNOWLEDGMENTS

We wish to acknowledge the technical assistance of E. A. McComb, A. Bevenue, M. C. Long, E. F. Potter, K. T. Williams, and E. J. Eastmond with the analyses, of J. C. Lewis in the preparation of the manuscript, of George Kennedy of Redwood City, Calif., for his cooperation in testing the mycelium in his mushroom beds, and N. F. Bracelin in the preparation of the figures.

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THE GENERA LEPTOSPHAERIA, PLEOSPORA, AND CLATHROSPORA IN MT. RAINIER NATIONAL PARK

LEWIS E. WEHMEYER

(WITH 24 FIGURES)

During the summer of 1948, Dr. A. H. Smith (**4**) conducted a party to Mount Rainier National Park for the purpose of collecting fungi and lichens in that region. Being interested in the distribution of the stem fungi of such mountain regions but unable to accompany the party, the writer was anxious to have Mr. Emory G. Simmons, who is capably interested in this group, make collections in this area. This was made possible through a grant from the Faculty Research Fund of the University of Michigan.

Mr. Simmons made extensive collections on both woody and herbaceous stems. A study of this material is of particular interest when compared with collections previously made from northwestern Wyoming (**6**). As in Wyoming, the predominant genera on herbaceous stems were *Leptosphaeria* and *Pleospora*. The fungus flora on stems shows a general similarity in both areas, but certain distinct differences are also apparent. Although both areas have many ecological factors in common, there are also some differences in this respect. Although of only slightly higher latitude and with even a less severe winter climate, the tree line on Mount Rainier (7000 ft.) is lower than that in the Tetons (about 10,500 ft.) of Wyoming. This is due, in part, to the much greater snowfall on Mt. Rainier and its persistence into the late summer in the sub-alpine zone (4500–7000 ft.). This zone with its mountain meadows and herbaceous vegetation supplies the host plants for the abundant stem-inhabiting fungi. The number of genera and species of host plants seems to be somewhat less on Mount Rainier than in Wyoming, but the number of species of fungi is just as great. Most of the fungous species are not limited by the species or genus

of the host, but rather by the physical character of the host stem, grasses, for instance, having a rather characteristic flora.

All collections were made in 1948 and in Mount Rainier National Park, unless otherwise stated.

TABLE I

Coll. No.	Host	Spores	Asci	Perithecia
		Leptosphaeria Doliolum		
R2153	Senecio	19–23 × 3.5–4	75–90 × 7–9	250–400
		Leptosphaeria Typharum		
R2194	Festuca	17–23 × 7	60–75 × 12.5–14	100–150, D*
R2289	Poa	17.5–19.5 × 5.5–6	42–53 × 14–16	50–100
R2187b	Agrostis	18–20 (23) × 7	55–65 × 14–18	100–300, D
R2271	Carex	19–21 × 7	70–78 × 14–15	
R2279	Phleum	21–23 × 7	53–60 × 14–16	200–300, D
R2193	Festuca	21–24.5 × 7.5–8.5	70–85 × 16	200–300, D
R2209c	Muhlenbergia	21–25 × 6.5	70–90 × 14–16	250 × 200
R2277	Festuca	23–26.5 × 7	70–80 × 16	250–300, D
R2288	Poa	23–28.5 × 6–7.5	60–90 × 16–19	250–300, D
R2192	Poa	25–28 × 6–7	90–110 × 16–18	150–250, D
R2200	Muhlenbergia	26–28 × 7–8	78–90 × 16–18	250–350, D
		Leptosphaeria vagans		
R2201a	Phleum	24.5–28.5 × 10–11	80–90 × 17–21	200–300, D
R2199	Festuca	24–32 × 10–11	88–95 × 23	250–350, D
R2213	Danthonia	26–30 × 10.5–12.5	85–90 × 21–23	250–350, D
R2211	Poa	26–33.5 × 9–12.5	75–95 × 21–25	200–250, D
		Leptosphaeria praeclara		
R1381a	Grass	26–28 × 7	60–70 × 12	350–450
		Leptosphaeria culmifraga		
R1451	Poa	21.5–25 × 3.5	70–80 × 8–9	300–400
R2285	Glyceria	25–28 × 5.5	75–105 × 8.5–10	250–500, t*
R2276	Grass	26–30 × 3.5–5	75–95 × 8.5–10.5	250–350, t
R2281	Glyceria	26–32 × 4–5	85–90 × 8.5–9	200–400, t
R2202	Calamagrostis	26–35 × 6–7	78–88 × 9–10.5	200–400
R2286	Agrostideae	28.5–31 × 5.5	90–110 × 10–11	250–400
R2215	Elymus	28.5–31 × 5–5.5	90–110 × 12.5–14	350–450, t
R2278	Agropyron	28.5–33 × 5–5.5	88–100 (140) × 10.5–12.5	400–450, t
R2186	Elymus	28.5–35 × 5–6	90–95 × 10–12.5	200–450
R2203	Cinna	29.5–33 × 4	85–100 × 9–10	250–450, T
R2279b	Phleum	30–35 × 4–5.5		400–500
R2282	Glyceria	30–35 × 5–5.5	90–110 × 9–10	300–400
R2199b	Festuca	31–35 × 4–5.5	100–110 × 12.5–14	400–450, T
R2212	Agrostis	32–35 × 5–5.5	90–100 × 10–11	350–500, t
R2199a	Poa	32–36 (42) × 5–6		300–450
R2185	Agrostis	32–42 × 5–5.5	80–90 × 10–12.5	300–400, T
R2209d	Muhlenbergia	33–40 × 5.5–6	90–110 × 13–17	400–500
R2207	Phleum	33–37 × 5–6	90–115 × 12.5	450
R1445	Agrostis	34–37 × 5–5.5		300–400

* The letter "D" stands for depressed, and the letter "T" for tomentose perithecia; small letters indicate a lesser degree of the same character.

TABLE I—*Continued*

Coll. No.	Host	Spores	Asci	Perithecia
		Leptosphaeria culmifraga		
R2280	Cinna	35–37 × 5–5.5		300–400
R1574a	Phleum	35–44 × 6–7	100–110 × 14–17	300–400, T
R2188a	Festuca	35–48 × 5.5–7	100–108 × 13–14	300–500, T
		Leptosphaeria elongata		
R2214	Calamagrostis	36–40 × 5.5–6.5	90–125 × 14	300–400, D, T
R2195	Elymus	43–53 × 5.5–7	125 × 16–18	250–500, T
		Leptosphaeria Baldingerae		
R1746b	Composite	40–46 × 10–12	140–160 × 18–21	300–400, t

LEPTOSPHAERIA CES. & DE NOT.

The species of this genus are very abundant in the Mount Rainier collections. The perithecia tend to be more thickly scattered or more closely crowded than those of the genus *Pleospora*, but are difficult to separate from that genus macroscopically.

TABLE I gives the data of a somewhat heterogenous group of species, all of which have certain distinctions in common from those presented in TABLE II. All of the collections in TABLE I have comparatively dark brown spores and they all lack a prominent swollen cell, except those of *L. culmifraga*. Most of them are also found on grass stems. The species in TABLE II include those referred to the "*agnita*" series in the Wyoming study (**6**). They seem to represent a discrete line of development. They have a pale yellow or yellow-green color in the spores, which also always show an eccentrically placed swollen cell and small droplets near the cross walls.

The greater number of species on grasses from Mount Rainier is due, in part at least, to the fewer collections made on grasses in Wyoming. *L. Doliolum* (Pers.) Ces. & de Not., *L. Typharum* (Desm.) Karst., and *L. vagans* Karst. belong to the same species complex, with 3-septate spores (FIGS. 1, 2) as the *L. eustoma* (Fr.) Sacc. and *L. Euphorbiae* Niessl reported from Wyoming, but differ in minor details.

L. culmifraga (Fr.) Ces. & de Not. and *L. elongata* sp. nov. are closely related species on grasses with spores (FIGS. 3, 4) sometimes showing an inflated cell, and with a single large oil globule in each cell. Such forms were not seen from Wyoming but probably exist there. The collection here referred to *L. Baldingerae* Fautr. & Lamb. resembles the *Leptosphaeria* sp. reported from

TABLE II

Coll. No.	Host	Spores	Asci	Perithecia
		L. oreophila		
R1406c	Ligusticum	20–35 × 4–5.5		350–500
R1604	Hieracium	26–30 × 6–7	70–90 × 9–11	200–300
R1492	Stems	28–32 × 4.5–5.5	90–110 × 11	250–300
R1441a	Hieracium	28–33 × 4–5.5	90–105 × 8–9	250–300
		L. Bupleuri		
R1620	Pedicularis	35–41 × 5–5.5	78–105 × 11–12	250–350
		L. tenera		
R2197	Cinna	19–26 × 3.5	62–70 × 7–8.5	200–300, T
R1439	Arabis	20–25 × 3.5–4.5	75–90 × 7	200–300
R2274	Carex	23–26.5 × 2.5–3.5	55–75 × 9–10	200–250
		L. norvegica		
R1456	Scirpus	28–35 × 5–6	90–110 × 11–13	200–300
		L. Salsolae		
R1947	Lupinus	40–48 × 5.5–6	90–199 × 14–16	300–350
R1492c	Stem	43–53 × 5–5.5	90–100 × 9–11	300–400
R1604a	Hieracium	44–53 × 5–5.5	85–100 × 14–16	400–500
		L. agnita		
R2343	Lupinus	31.5–43 × 5–5.5	105–150 × 13–15	300–400
R1425	Lupinus	41–46 × 4.5–5.5	105–130 × 11–14	300–400
		L. Erigerontis		
R1406a	Ligusticum	43–57 × 5–5.5	85–110 × 12.5–15	300–400
R1443a	Mertensia	47–65 × 6–7	105–125 × 14–16	300–400, T
R1749	Valeriana	50–58 × 5–6	95–135 × 14–17	400–500
R1610a	Valeriana	53–58 × 5.5–6		300–350
R2338	Valeriana	53–58 × 5–5.5	110–160 × 12.5–14	250–400
R1955	Lupinus	53–60 × 5–6	105–115 × 14–16	300–500, t
R1952	Ligusticum	53–60 × 5.5–6.5	105–120 × 16–18	300–400, T
R1937	Lupinus	55–68 × 5.5–7	105–115 × 12.5–14	300–400
R1957	Ligusticum	56–68 × 5–6	105–140 × 14–16	250–450, T
R1590b	Valeriana	58–62 × 5.5–6	90–105 × 14	250–400
R1954	Pedicularis	58–65 × 5–6	88–96 × 16–18	250–300, T
R1941	Ligusticum	60–68 × 7–7.5	90–105 × 17–19	300–400
R1942	Ligusticum	64–75 × 6–7	105–125 × 14–16	300–400

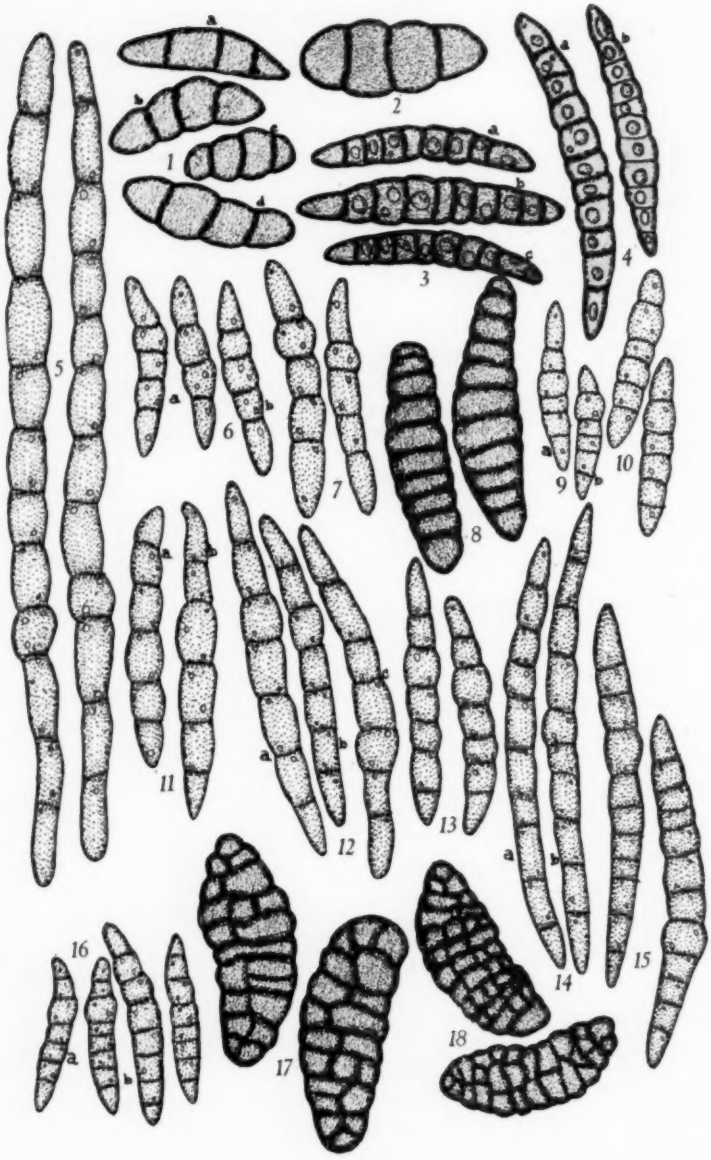
TABLE II—*Continued*

Coll. No.	Host	Spores	Asci	Perithecia
		L. asparagina		
R2185a	Agrostis	19.5–25 × 3.5	78–90 × 8.5–10.5	200–400, T
R1574	Phleum	21–26 × 3.5–4	75–90 × 8–9	300–400
R2207a	Phleum	21.5–25 × 4–5	60–78 × 7–9	250–300, T
R1383a	Heracleum	23–26 × 5–5.5	70–78 × 9–11	250–350, T
R2191	Festuca	23–28.5 × 5–5.5	60–75 × 9–12.5	300–450, T
R2206	Elymus	24.5–27 (30) × 3.5–4.5	60–70 × 10–11	300–400, T
R2196	Festuca	25–30 × 5–6	70–85 × 10–12	300–400, T
R2210	Elymus	26–30 × 4.5–5	85–90 × 12.5	350–400, T
R2205	Calamagrostis	30–35 × 5–5.5	90–105 × 10–12	300–400, T
		L. Drabae		
R1747	Composite	70–76 × 5–5.5	90–105 × 16–18	250–400, T
R1493b	Valeriana	70–79 × 4.5–5.5	90 110 × 16–18	300–400
		L. multiseptata		
R1603	Achillea	55–65 × 6–7	85–100 × 16–17	300–400
		L. filiformis		
R1746a	Composite	140–155 × 5–6	140–200 × 16–19	300–450

Wyoming on *Agastache,* but has nine to ten (FIG. 8) rather than five to six septa as in the Wyoming species.

The group of species included in TABLE II are the most abundant on non-grass hosts in both regions and were previously referred to as the *"agnita"* series. The species differ in size and septation of the spores (FIGS. 5, 6, 7, 10–16) but show a continuous series in these respects. The Mount Rainier collections show a greater range of variation (ten species) in this group than those from Wyoming (six species), indicating that the increase in length and number of septa has progressed in a somewhat independent manner.

A very similar group of species also occurs in Europe. Guyot *et al.* (**2**) have recently reported upon a study of a group of collections of *Leptosphaeria* all of which they refer to *L. Niessleana* Rab. There is no doubt that the collections previously referred to *L. oreophila* (**6**) belong in this same species, *L. Niessleana,* in fact Guyot gives *L. oreophila* as a synonym of *L. Niessleana.* These collections of Guyot show a good deal of variation in perithecial characters and spore size and septation. The ascospores vary from 25–55 × 4–8 μ. They are mostly 4-septate with the second cell



FIGS. 1–18.

swollen, but some collections show 3-, 5-, or even 6-septate spores, and occasionally have the third cell swollen. This widening of the species concept would include the collection placed here under *L. Bupleuri*, or even *L. tenera*, *L. norvegica*, or other species. In these latter species however, on Mount Rainier, the greater per cent of the spores are 5- or more septate, whereas in *L. Niessleana* most of the spores are 4-septate. Guyot states that the young perithecia have a characteristic penicillate ostiole but this was not outstanding in our material. He also states that the distribution of *L. Niessleana* is largely "boreo-alpin," in central and northern Europe.

It is interesting to find this same group of *Leptosphaeria* species in similar ecologic regions in Europe and the Cascade and Rocky Mountain ranges of North America. In America the development of the spore seems to have gone farther and to show a greater range in variation. This may be only an apparent difference, however, for further study of European material may show the same range of variation in spore septation and size.

In both the genera *Leptosphaeria* and *Pleospora* we can look upon the three-septate spore as the basic type. The first species, *L. Niessleana* Rab. of this series has spores (FIG. 6) which are 4-septate and are obviously derived from the 3-septate spore by the insertion of an additional septum in the lower half and the inflation of the cell above the central primary septum. All of the Mount Rainier collections with this type of spore, except one, had spores with a size range corresponding closely to that of the previous collections seen from Wyoming. The one exception had definitely larger spores (FIG. 7) and was placed in *L. Bupleuri* Syd. The Rainier collections of *L. Niessleana* often show some spores with only three septa, in which case, also, the swollen cell is the second one from the upper end, indicating that the additional septum is inserted in the lower end. In one of the Wyoming collections (*W1045*), some 5-septate spores occur, in which case the additional septum is in the upper cell and the inflated cell is then the third from the upper end.

L. tenera Ellis has 5-septate spores (FIG. 9) in which both additional septa are laid down in the lower end of the spore and the swollen cell is still the second from the upper end. Here again,

two collections from Rainier had spores of the same size range as those from Wyoming, whereas a single collection had definitely larger spores (FIG. 10) and is placed in *L. norvegica* Rostr.

The collections here placed under *L. Salsolae* Hollos are somewhat doubtful but the spores (FIG. 11) are 5-septate and seem to be derived from the 3-septate spore by the insertion of a septum both above and below the central primary septum. In this case the third cell is the inflated cell and there are two rather than three septa below this cell. No such spore form was seen in the Wyoming collections.

An interesting situation exists as regards the 6-septate species of this series. The spore forms previously (**6**, p. 237) used to distinguish *L. agnita* (Desm.) Ces. & de Not. and *L. Erigerontis* Berl. were also found in the Rainier material. The size range of the spores of *L. agnita* (FIG. 13) was very similar in both areas, but the spores of *L. Erigerontis* (FIG. 12) became much longer (up to 75 μ) on Mount Rainier than they did in Wyoming (up to 60 μ). This extension of spore size in Wyoming, on the other hand, is accompanied by a change in spore form which constitutes the species *L. olivacea* Ellis, which was not found in Washington. On Mount Rainier, again, there were a number of 6-septate collections, placed under *L. asparagina* Karst., in which the spores (FIG. 16) were smaller even than in *L. agnita*, but occasionally had a seventh septum in the lower end.

The 6-septate spore of these species is derived from the symmetrically 5-septate spore of such species as *P. Salsolae* by the insertion of an additional septum in the lower end, and so leaving the third cell inflated. In *P. asparagina* the seventh septum is also inserted in the lower end.

The Rainier collections placed under *L. Drabae* (Nyl.) Karst. are very similar in spore structure to the *L. octoseptata* described from Wyoming but in *L. Drabae* many spores (FIG. 14) have more than eight septa. *L. multiseptata* with 8- to 11-septate spores (FIG. 15) is similar to *L. Drabae*, but differs in the shorter, broader spores with more closely placed septae. Such a spore might have been derived from that of *L. asparagina* by the insertion of one or two septa above and two or three septa below the central primary

septum. From this viewpoint, *L. Niessleana, L. tenera, L. asparagina,* and *L. multiseptata* can be looked upon as a sub-series in which the spores have remained shorter and with more closely placed septa. *L. filiformis,* on the other hand has spores (FIG. 5) much longer than those of *L. Drabae,* but with the same septation. Neither *L. multiseptata* nor *L. filiformis* was found in Wyoming. An interesting observation which seems to be more than mere coincidence is that of the collections of *L. Niessleana, L. tenera, L. Bupleuri, L. norvegica, L. asparagina,* and *L. multiseptata,* except one (*R1620* of *L. Bupleuri*) were collected at an elevation of 4600 feet or less, whereas all the collections, except one (*R1443a* of *L. Erigerontis*) of *L. agnita, L. Erigerontis, L. Drabae,* and *L. filiformis* were collected above 4600 feet. It will be noted that the low-altitude group corresponds very well with the short-spored sub-series and the high altitude group with the long-spored sub-series. In Europe, Guyot (2) states that *L. Niessleana* occurs below 1500 meters (4500 feet) only in the far north, *i.e.,* in Finland and Scandinavia. In Wyoming, all the species of these two series were collected above 6000 feet, but it is true that those which might be considered in the second series, *i.e., L. agnita, L. Erigerontis, L. octoseptata,* and *L. olivacea,* all came from higher altitudes of 8000–10,000 feet. This may be merely another reflection of the fact that climate and snowfall on Mount Rainier give rise to an alpine ecological site at much lower altitudes than say the Rocky Mountains, or the central European Alps.

LEPTOSPHAERIA DOLIOLUM (Pers.) Ces. & de Not.

Perithecia thickly scattered, 350–400 μ in diameter; walls 30–40 μ thick, of small-celled parenchyma. Asci long-clavate, tapered at the base, 75–90 × 7–9 μ, with numerous interthecial strips. Spores biseriate, fusoid, 3-septate, pale yellow, tapered, inequilateral to curved, not constricted, 19–23 × 3.5–4 μ.

Collection: *R2153,* on *Senecio triangularis,* Beaver Marsh, Longmire, Washington, 2700 feet, July 3.

This collection differs from typical *L. Doliolum* in the less stromatic development of the perithecial walls, and the rather long, narrow, very light colored spores, but these characters may be due to immaturity, and it seems best placed in this species.

LEPTOSPHAERIA TYPHARUM (Desm.) Karst. sensu Berl. FIG. 1

Perithecia 200–350 × 100–200 × 50–150 μ, flattened ellipsoid, usually thickly scattered, sometimes sparsely distributed, usually arranged in longitudinal series between the main bundles and erumpent as papillate ostioles or elongate black carbonaceous streaks, occasionally as circular blackened spots with a light colored central area; walls thin, 10–20 μ thick, parenchymatous.

Asci broad-clavate to cylindric-clavate, apical wall somewhat thickened, base slightly claw-like, 60–110 × (12.5–)14–18 μ.

Spores crowded or overlapping biseriate, ellipsoid to fusoid, yellow-brown or yellow, 3-septate, usually inequilateral or curved, ends mostly bluntly rounded, but sometimes tapered, usually slightly constricted at the septa but sometimes not so, (17–)20–28 × 6–8 μ.

Collections: *R2187b*, on *Agrostis* sp., Yakima Park Road, 6400 feet, August 18; *R2192*, on *Poa epilis*, Indian Henry's Hunting Ground, 5500 feet, August 2; *R2193*, on *Festuca viridula*, Eagle Peak, 5800 feet, July 29; *R2194*, on *Festuca* sp., Eagle Peak, 5500 feet, July 29; *R2200* (5500 feet, August 2) and *2209c* (5200 feet, July 18), on *Muhlenbergia filiformis*, Indian Henry's Hunting Ground; *R2271*, on *Carex* sp., Berkeley Park, 6000 feet, August 17; *R2277*, on *Festuca*, Mazama Ridge, 5700 feet, July 21; *R2279*, on *Phleum* sp., Louise Lake, 4600 feet, July 13; *R2288*, on *Poa* sp., Mazama Ridge, 5700 feet, July 21; *R2289*, on *Poa* sp., Mazama Ridge, July 21.

This *Leptosphaeria* is found upon many of the grass collections from this area and is characterized by the small, elongate, flattened, ellipsoid perithecia and the 3-septate inequilateral spores. There is a large range of variation in size of spores, however, as is shown in TABLE I. There is also some variability in the amount of constriction at the septa and the taper or bluntness of the ends of the spores. Collections Nos. *2192*, *2200*, and *2209c* have spores (FIG. 1, a and b) in which the ends of the spores are more gradually tapered and in which the constrictions are very slight or lacking, particularly in *2209c*. It is interesting to note that all three of these collections come from the same locality. There have been literally scores of species described with spores of this general type, yet these collections all seem similar and closely related. Unless one describes every collection as a new species, it is practically impossible to assign binomials in any satisfactory manner in this group. Berlese (**1**, p. 66) groups a number of species on grasses,

with spores similar to those of these collections, under the binomial *L. Typharum*, and his usage is followed here. This group is very similar to another ubiquitous group, which Berlese (**1**, p. 55) has grouped as forms under the name of *L. eustoma* (Fr.) Sacc. This binomial was used by the writer (**6**) for several Wyoming collections on dicotyledons, which have slightly smaller, narrower spores and more globose perithecia. Actually, *L. eustoma* has been generally used for a graminicolous *Leptosphaeria*.

LEPTOSPHAERIA VAGANS Karst. sensu Berl. FIG. 2

Collections: *R2211*, on *Poa epilis*, and *R2213*, on *Danthonia intermedia*, from Mazama Ridge, 5700 feet, July 21; *R2201a*, on *Phleum alpinum*, Van Trump Park, 5800 feet, July 26; and *R2199*, on *Festuca rubra*, Eagle Peak, 5800 feet, July 29.

These collections are similar in all respects to those described under *L. Typharum*, except that the asci are broader (85–90 × 21–23 μ) and the spores are larger and broader (28–30(–33) × 10.5–12.5 μ), have more broadly rounded ends and are usually straight rather than inequilateral. It is a continuation of the same series on grasses, but the spores are so extreme that it deserves specific separation. *L. Typharum* var. *phragmitina* Karst., and *L. Bambusae* (Miy. & Hara) Sacc. are the only two species on grasses that have similar spores described for them, but these are both on much larger grasses. Berlese, again, figures and describes (**1**, p. 67; *Pl. 52*) *L. vagans* Karst. and *L. junciseda* Karst. as having similar spores, 30–33 × 9–11 μ, and the former epithet is here used for these collections.

All of the collections of both this species and *L. Typharum* were taken above an elevation of 5500 feet.

LEPTOSPHAERIA PRAECLARA Karst.

Perithecia 350–450 μ in diameter, flattened-globose to conic, clustered on somewhat blackened areas of the stem, immersed but strongly erumpent as a broad cylindric to conic or often somewhat flattened ostiole; wall 40–60 μ thick above, some 20 μ on the lower face, plectenchymatic.

Asci clavate, tapered below when older, 60–70 × 12 μ.

Spores biseriate to triseriate, long fusoid, yellow-brown, 5-septate, somewhat inequilateral or curved, tapered toward bluntly rounded ends, constricted at the septa, sometimes more tapered toward the lower end and with a slightly enlarged third cell, 26–28 × 7 μ.

Collection: *R1381a*, on grass stems, Bad Lands Nat. Monument, Pennington, South Dakota, June 21.

This collection did not come from the Mount Rainier area, but is included as an interesting one on grass stems. The rather large, irregular, often flattened ostioles might have resulted in the placement of this specimen in the genus *Lophiostoma*. *Lophiostoma macrostomoides* de Not. and *L. pseudomacrostomum* both have similar spores, but the asci in these species are longer and narrower. The broader, shorter asci of this collection fit better a group of species of *Leptosphaeria* on grasses including *L. praeclara* Karst., *L. typhiseda* Sacc. & Berl., *L. Rehmii* Mout. and *L. recessa* Pass. *L. typhiseda* is perhaps closest to this collection. Berlese (**1**, p. 75) places this species as a form of *L. praeclara*, which in turn has a broader range of spore size (20–32 × 8–9 μ) and is the older binomial.

LEPTOSPHAERIA CULMIFRAGA (Fr.) Ces. & de Not. FIG. 3

Perithecia 300–550 × 200–350 μ, flattened spheric, rather thickly scattered or clustered at the nodes, pustulate-erumpent by the papillate to short conic ostioles; wall 20–40 μ thick, of dark brown parenchyma, sometimes covered with a dense tomentum, at other times with tomentum inconspicuous or lacking.

Asci long-clavate with a long tapered base, apical wall somewhat thickened, 80–110 × 10–15 μ, interthecial strips not abundant.

Spores 2- to 4-seriate, overlapping, long-fusoid, yellow to yellow-brown, 8–9-septate, third cell commonly somewhat enlarged, usually inequilateral or curved, not or only slightly constricted at most septa, tapered toward the ends, 29–44 × 5–6(–7) μ.

Collections: *R1451*, on *Poa* sp., Longmire Springs, 2700 feet, July 9; *R1574a*, on *Phleum pratense*, Longmire, Washington, 2700 feet, July 20; *R2185*, on *Agrostis* sp., Rd. to Paradise, 3500 feet, August 14; *R2186*, on *Elymus glaucus*, Takoma Cr., August 9; *R2188a*, on *Festuca viridula*, Berkeley Park, 6000 feet, August 17; *R2192a*, on *Poa epilis*, Henry's Hunting Ground, August 2; *R2199b*, on *Festuca rubra*, Eagle Pk., 5800 feet, July 29; *R2202*,

on *Calamagrostis* sp., Nisqually Glacier, 3900 feet, July 15; *R2203*, on *Cinna latifolia*, Longmire Hot Spr., 2700 feet, July 9; *R2207*, on *Phleum pratense*, Nisqually Glacier, 3900 feet, July 15; *R2209d*, on *Muhlenbergia filiformis*, Indian Henry's Hunting Ground, 5200 feet, July 18; *R2212*, on *Agrostis* sp., Louise Lake, 4600 feet, July 13; *R2215*, on *Elymus glaucus*, Wonderland Trail, 3200 feet, July 11; *R2276*, on Grass, Wonderland Trail, 4500 feet, July 11; *R2279b*, on *Agropyron* sp., Louise Lake, 4600 feet, July 13; *R2281*, on *Glyceria* sp., Longmire, July 3; *R2285*, on *Glyceria* sp., Narada Falls, 4000 feet, July 4; *R2286*, on Agrostideae, Narada Falls, 4600 feet, July 4.

This is one of the most common species on grasses, particularly at lower altitudes, where it can be found on almost every collection. It differs in macroscopic appearance from *L. Typharum* in the larger, more spheric, more tomentose and more scattered perithecia.

The various interpretations of this binomial no doubt include several species. Saccardo (**3**, vol. 2) and Winter (**12**, p. 456) give the spores as 7–9-septate, 35–46 × 5–7 μ, and with the third cell swollen. Berlese (**1**, p. 84) says the spores are 35–38 × 5–6 μ and figures (*Pl. 76*) them with the second cell enlarged.

Leptosphaeria elongata sp. nov. FIG. 4

Perithecia 250–500 μ diametro, 200–300 μ alta, oblate ellipsoidea, dispersa, atrotomentosa, in superficie sicut maculae minutae cum ostiolo centrali, vix erumpente, pariete 30–50 μ crasso, atro, ex cellulis parenchymatosis compressis composito.

Asci longe clavati, 90–125 μ longi, 14–18 μ crassi, basi angustati, membrana apice paululo crassa.

Sporae 36–55 μ longae, 5.5–7 μ crassae, 2- vel 4-seriatae, longe cylindrici-fusiformae, luteae vel luteo-brunneae, plerumque 9- vel 10-septatae, interdum 8- vel 11-septatae, cellula quarta (vel raro tertia) subinflata (sed saepe in sporis juvenilibus cellula inflata deest), plerumque subcurvatae, paululo ad septa constrictae, utrinque gradatim angustatae, juveniles guttulis oleoginis praeditae.

Specimen typicum legit Wehmeyer in (n. *R2195*), in caulibus *Elymi glauci*, secus viam "Dege Peak," alt. 6800 ped., 19 Aug., 1948.

Perithecia 250–500 × 200–300 μ, flattened ellipsoid, scattered, appearing on surface as small blackened spots with a barely erumpent, papillate ostiole; wall 30–50 μ thick, of compressed, dark brown parenchyma, and clothed with a dark brown tomentum.

Asci long-clavate with a tapered base, apical wall slightly thickened, 90–125 × 14–18 μ.

Spores biseriate to 4-seriate, long cylindric-fusoid, yellow to yellow-brown, mostly 9–10-septate, occasionally 8–11-septate, fourth, or occasionally the third cell somewhat inflated, at other times, particularly in young spores, no inflated cell obvious, usually somewhat curved, slightly constricted at the septa, gradually tapered toward somewhat rounded ends, with large oil drops in each cell when young, 36–55 × 5.5–7 μ.

Collections: *R2195* (type), on *Elymus glaucus*, Dege Peak Trail, 6800 feet, August 19; and *R2214*, on *Calamagrostis canadensis*, Narada Falls, 4600 feet, July 4.

These collections have quite variable spores which seem to be a natural continuation of the variation of *L. culmifraga*, as here delimited, but they are somewhat larger, more commonly 9–10-septate and usually with the fourth instead of the third cell inflated. They would fall within the conception of *L. dolioloides* (Awd.) Karst., as given by Saccardo (**3**, vol. *2*: 44) (with spores 7–11-septate and 35–65 × 3–5 μ), but this range probably would include a number of species. Berlese (**1**, p. 85) and Winter (**11**, p. 483) interpret this same species as on composites but with spores 35–42 × 3–4 μ. This conception fits better with that found by the writer (**5**, p. 583) for Nova Scotian specimens, which have narrower spores and more strongly tapered to more pointed ends, than this species on grasses. The variety *propinqua* Sacc. of *L. culmifraga* is described as having the fourth cell inflated, but with only 7–8 septa in the spores. *L. mosana* Mout. is very similar but described as having clavate-fusiform spores 7–9-septate and 7–9 μ in diameter. There seems to be no species on grasses described with spores as in these collections.

LEPTOSPHAERIA BALDINGERAE Fautr. & Lamb. FIG. 8

Perithecia 300–400 μ in diameter, scattered, soon superficial; with a tomentum of a few stiff hairs.

Asci cylindric-clavate, with a claw-like base, and a thickened apical wall, 140–160 × 18–21 μ.

Spores overlapping biseriate, broad cylindric-fusoid, yellow to dark yellow-brown, 9–10-, rarely 11-septate, usually inequilateral or somewhat curved, slightly tapered, but ends broadly rounded, fifth cell at broadest point of spore and usually somewhat enlarged, constricted at all septa, 40–46 × 10–12 μ.

Collection: *R1746b,* on Composite, Indian Henry's Hunting Ground, 5500 feet, August 3.

There is rather scant material of this fungus in this collection, but it fits very well the description of *L. Baldingerae,* and even though that species was described on a grass this collection is referred here rather than to base a new species on scant material.

LEPTOSPHAERI NIESSLEANA Rab. FIG. 6

This species was previously discussed (**6**) under the name of *L. oreophila,* which was shown by Guyot (**2**) to be a synonym of *L. Niessleana.* The collections from Mount Rainier were as follows:

R1406c, on *Ligusticum purpureum,* Narada Falls, 4600 feet, July 2; *R1492,* on herbaceous stems, Lake Louise, 4600 feet, June 13; *R1604,* on *Hieracium albiflorum,* Carbon Glacier, 4000 feet, July 8.

This species can be considered as the one having the basic septation from which the species in TABLE II have been derived. The range of spore size of the Mount Rainier specimens was about the same as those obtained in Wyoming, but a greater number of spores with only three septa were found in the Mount Rainier material, particularly in the case of the smaller spores of collections Nos. *1406c* and *1604.* This may have been due to an immature condition of these specimens, but Guyot (**2**) found the same to be true in his European material.

LEPTOSPHAERIA BUPLEURI Syd. FIG. 7

Perithecia 250–350 μ in diameter, globose sparsely scattered, erumpent as a papillate ostiole; wall 20–30 μ thick, composed of black parenchyma, not tomentose.

Asci numerous, clavate, tapered toward the base, apical wall not thickened, 78–105 × 11–12 μ.

Spores 2- to 3-seriate, cylindric-fusoid, pale yellow, mostly 4-, rarely 3- or 5-septate, constriction above the middle with usually one septum above and two below the constriction, slightly constricted at the other septa, straight or slightly curved, slightly tapered, 35–41 × 5–5.5 μ.

Collection: *R1620,* on *Pedicularis contorta,* Van Trump Trail, 5300 feet, July 25.

The spores of this one collection have the septation of those of *L. Niessleana*, but are distinctly larger. There are several species in the literature described as having such spores. They are *L. Bupleuri* Syd., *L. oreophiloides* var. *Scrophulariae* Karst., *L. aquilina* D. Sacc., and *L. cylindrospora* Awd. The first two are cited as synonyms of *L. Niessleana* by Guyot (**2**), who extends the spore range of the latter species to 55 μ. In the western American material, however, there seems to be a definite break separating this collection, and the range of spore size will probably be extended. A collection made by W. B. Cooke on Mount Shasta, for instance, has spores 49–54 × 5.5–6 μ, and the septation of *L. Bupleuri*. It would fall in the range of *L. cylindrospora* or *L. aquilina*.

LEPTOSPHAERIA TENERA Ellis. FIG. 9

Three collections of this species from Mount Rainier agreed with the description previously given for the collections from Wyoming (**6**).

Collections: *R1439*, on *Arabis Drummondii*, Nisqually Glacier, 4000 feet, July 8; *R2197*, on *Cinna latifolia*, Comet Falls Trail, July 25; *R2274*, on *Carex* sp., Wonderland Trail, July 11.

This species is easily derived from *L. Niessleana* by the insertion of another septum in the lower end of the spore, and if the collection placed in the following species, *L. norvegica*, be included, both species cover much the same range in spore size.

LEPTOSPHAERIA NORVEGICA Rostr. FIG. 10

Perithecia 200–300 μ in diameter, somewhat flattened-spheric, widely but sparsely scattered, immersed, appearing on the surface as small annular black spots with a light-colored center.

Asci numerous, clavate, tapered toward the base, apical wall thickened, 90–110 × 11–13 μ.

Spores 3–4-seriate, cylindric-fusoid, honey-yellow, 5- (rarely 6-) septate, constricted somewhat above the middle, with one septum above and three septa below the constriction, second cell usually somewhat swollen but sometimes not, straight or slightly curved, not much tapered, 28–35 × 5–6 μ.

Collection: *1456:* On *Scirpus microcarpus*, Wonderland Trail, Longmire, Washington, 4000 feet, July 11, 1948.

This collection has the same septation as *L. tenera,* but the spores are larger. There are a score or so of species, all very similar to this one. Most of these have smaller spores or show the third, rather than the second cell, inflated. The binomial *L. norvegica* is chosen because it shows none of these discrepancies, although the spores are slightly smaller (28–30 × 5 μ) than those of this collection. *L. occulta* Lind, as described, is also similar, but with larger spores (36–40 × 4 μ).

LEPTOSPHAERIA SALSOLAE Hollos. FIG. 11

Perithecia 300–500 μ in diameter, globose or depressed-spheric, rather thickly scattered, immersed, then erumpent; wall 20 to 60 μ thick, of coarse black parenchyma.

Asci clavate, tapered toward the base, wall not strongly thickened, 85–100 × 9–16 μ, imbedded in interthecial strips.

Spores overlapping-fasciculate, cylindric-fusoid, pale yellow-brown, 5-septate, third cell somewhat swollen, straight or slightly curved, slightly tapered, 40–53 × 5–6 μ.

Collections: *R1492c,* on herbaceous stem, Louis Lake, 4600 feet, July 13; *R1604a,* on *Hieracium albiflorus,* Carbon Glacier, 3500 feet, July 22; *R1947,* on *Lupinus volcanicus,* Summerland, 5500 feet, August 16.

The spores of these collections are 5-septate with the third cell swollen. Many of the spores of *1492c* show the characteristic shape, previously mentioned by the writer (**5**) for the species *L. ogilviensis,* but these spores are larger than in that species (30–40 × 4–5 μ). Here again, sufficient collections will show a series with this spore form and a wide range of spore size, as is indicated by an examination of various exsiccati. These three collections are not in very good condition and further study of this group is to be desired. *L. Feltgeni* Sacc. & Syd. has spores described for it which are very similar to those here considered, but as this name was created for a *Leptosphaeria* sp. of Feltgen, whose material is notoriously poor, Hollos' later name is adopted.

LEPTOSPHAERIA AGNITA (Desm.) Ces. & de Not. FIG. 13

This species, as circumscribed in the Wyoming studies (**6**) for those collections having spores 35–45 μ long, with six septa, the

third cell somewhat enlarged, and the third septum at about the middle of the spore, was also represented in the Mount Rainier collections as follows:

R1425, and *R2343*, both on *Lupinus subalpinus*, from different areas about Reflection Lake, 4865 feet, July 5.

It is interesting to note that these two collections again came from *Lupinus*, as was the case with all of the Wyoming collections.

LEPTOSPHAERIA ERIGERONTIS Berl. FIG. 12

This species, as previously outlined (**6**) for collections with spores having the same septation as those of *L. agnita*, but larger and with the third septum above the middle of the spore, was again the most abundant *Leptosphaeria* in the Mount Rainier area, as it was in Wyoming.

Collections: *R1406a*, on *Ligusticum purpureum*, Narada Falls, 4600 feet, July 2; *R1443a*, on *Mertensia laevigata*, Nisqually Glacier Trail, 4000 feet, July 9; *R1590b* and *R1610a*, on *Valeriana sitchensis*, Mazama Ridge, 6000 feet, July 21; *R1749*, on *Valeriana sitchensis*, Indian Henry's Hunting Ground, 5500 feet, August 2; *R1937*, on *Lupinus volcanicus*, and *R1941*, on *Ligusticum purpureum*, Dege Peak Trail, 6800 feet, August 19; *R1942*, on *Ligusticum purpureum*, Summerland, 5500 feet, August 16; *R1952*, on *Ligusticum purpureum*, Yakima Park, 6400 feet, August 18; *R1954*, on *Pedicularis latifolia*, Berkeley Park, 6000 feet, August 16; *R1955*, on *Lupinus subalpinus*, Berkeley Park, 6700 feet, August 16; *R1957*, on *Ligusticum purpureum*, Berkeley Park, 6000 feet, August 17; *R2338*, on *Valeriana sitchensis*, Mazama Ridge, 5700 feet, July 21.

The collections included here have spores ranging in size over the entire range of both *L. Erigerontis* and *L. olivacea* as described from the Wyoming material, but the spores from Mount Rainier are all broad and tapered as in the former species. All but one of these collections (*R1443a*) come from elevations of 4500 feet or more.

LEPTOSPHAERIA ASPARAGINA Karst. FIG. 16

Perithecia 250–450 × 200–300 μ, somewhat flattened-spheric, rather sparsely scattered, immersed, erumpent as rather stout conic

ostioles; wall 20–40 μ thick, of dark brown parenchyma, and covered below by a coarse brown tomentum.

Asci clavate, with a long tapering base, apical wall somewhat thickened, 60–90 × 7–12.5 μ.

Spores overlapping biseriate, fusoid, yellow to yellow-brown, 6- or mostly 7- or 8-septate, straight or slightly curved, tapered toward the ends, constricted at the septa, most strongly just above the middle, one septum above and three or four below this septum, third cell swollen, 20–35 × 3.5–6 μ.

Collections: *R1383a,* on *Heracleum lanatum,* Nisqually River, 3700 feet, July 1; *R1574,* on *Phleum pratense,* Longmire, Washington, 2700 feet, July 20; *R2185a,* on *Agrostis* sp., Rd. to Paradise, 3500 feet, August 14; *R2191,* on *Festuca subulata,* Wonderland Trail, Takoma Park, 4600 feet, August 2; *R2196,* on *Festuca* sp., S. W. Entrance, July 28; *R2205,* on *Calamagrostis canadensis,* Nisqually Glacier, 3900 feet, July 15; *R2206,* on *Elymus glaucus,* Takoma Creek, 2400 feet, July 16; *R2207a,* on *Phleum pratense,* Nisqually Glacier Trail, July 15; *R2210,* on *Elymus virescens,* Carbon Glacier, 3500 feet, July 22.

This seems to be a rather abundant species. It differs from *L. tenera* in having an extra septum on each side of the main constriction. It occurs mostly on grasses, but occasionally on dicotyledons. The spores of these collections cover a fairly wide range in size which covers that of this species and *L. conimbricensis* Berl. Collections *R2205* and *R2210* have larger spores, 26–35 × 4.5–5.5 μ and occasionally show a spore with eight septa, and might be segregated under the name *L. amphibola* Sacc.

In contrast to the preceding species, these collections all come from elevations of 4600 feet or less.

LEPTOSPHAERIA DRABAE (Nyl.) Karst. FIG. 14

Perithecia 300–400 μ in diameter, globose or somewhat depressed, immersed at first, erumpent as a conic ostiole, rather thickly scattered; wall 30–40 μ thick, of dark colored parenchyma and clothed on the lower portion with a dense, long-sinuous, brown tomentum. Asci clavate, tapered toward the base, apical wall thickened, immersed between filiform interthecial strips, 90–110 × 16–18 μ.

Spores overlapping fasciculate, long fusoid-filiform, pale yellow, 8–10-, rarely 11-septate, straight or somewhat curved, tapered toward both ends, fourth cell somewhat swollen, usually four septa

below and two above this swollen cell, rarely six below or three above, 70–80 × 4.5–5.5 μ.

Collections: *R1493b*, on *Valeriana sitchensis*, Louise Lake, 4600 feet, July 13; *R1747*, on Composite stem, Indian Henry's Hunting Ground, 5500 feet, August 3.

The spores of these two collections are very similar to those described as *L. octoseptata* from Wyoming (**6**) and there is a legitimate question as to whether the range of variation of these two species is not a continuous one. As in many of the other collections from the west coast, these seem to be a continuation of the range of variation of those from the Rocky Mt. region. Collection No. *1747* has spores, most of which show four septa below the swollen cell, *i.e.*, are 8-septate, but some show five septa below, or are 9-septate. In No. *1493b*, most of the spores show nine definite septa and occasionally six septa appear below the swollen cell or three appear above it. *L. Drabae* is given as having spores 7–9-septate and might include all three of these collections.

LEPTOSPHAERIA MULTISEPTATA Wint. FIG. 15

Perithecia 300–400 × 200–250 μ, somewhat flattened-spheric, rather thickly scattered, formed beneath epidermis but soon erumpent as stout conic ostioles and soon superficial; walls 20–40 μ thick, of brown parenchyma, smooth.

Asci clavate, tapered toward the base, apical wall slightly thickened, 85–100 × 16–17 μ.

Spores fasciculate, long-fusoid, pale yellow, 9–11-(12-)-septate, fourth, or rarely the fifth, cell swollen, somewhat curved, tapered toward both ends, five, six, or rarely seven septa below the swollen cell and two or three above it, 55–65 × 6–7 μ.

Collection: *R1603*, on *Achillea Millefolium*, Carbon Glacier, 3500 feet, July 22, 1948.

The spores of this collection have much the same sort of septation as those placed under *L. Drabae*, but they are much smaller and the septa as a result are much more closely placed. There are a number of species described with similar spores, but none which seem to fit exactly. It might be placed in *L. dolioloides* (Awd.) Karst. as described by Saccardo (**3**; Vol. **2**: 44) who gives a wide range of spore size (35–65 × 3–5 μ), but other authorities seem to limit this species to collections with smaller spores (35–45 μ).

L. multiseptata Wint. and *L. Lathyri* Fautr. are probably the same species and their spores agree with this collection fairly well in size (42–55(–60) × 4–5 μ) and septation, but Winter (**12**, p. 482) states that the spores of *L. multiseptata* do not have a pronounced swollen cell. This is a variable character, however, and this name is used provisionally for this collection.

Leptosphaeria filiformis sp. nov. FIG. 5

Perithecia diametro 300–450 μ, 250–300 μ alta, oblate globosa, dispersa, immersa, erumpentia per ostiola crassa, papilliformia; pariete atro parenchymatoso.

Ascí 140–200 μ longi, 16–19 μ crassi, longe clavati, deorsum angustati, membrana paululo crassa, inter pseudoparaphyses immersi.

Sporae 140–155 μ longae, 5–6 μ crassae, longe cylindrico-fusiformae, fasciculatae in ascis, luteo-brunneae vel pallide luteo-brunneae, 10- vel 11-septatae, utrinque angustatae, modice curvatae, ad septa paulum constrictae, cellula quarta inflata, guttulis paucis ad septa praedita, septis 6 vel 7 infra cellulam inflatam et 2 supra eam.

Specimen typicum legit Wehmeyer (num. *R1764a*) in caulibus Compositarum, "Indian Henry's Hunting Ground"; Alt. 5500 ped., 3 Aug., 1948.

Perithecia 300–450 × 250–300 μ, depressed-spheric, scattered, immersed, erumpent as stout papillate ostioles, finally superficial, wall 40–60 μ thick, composed of compact black parenchyma, not tomentose.

Asci long-clavate, tapered toward the base, apical wall not much thickened, 140–200 × 16–19 μ, imbedded in numerous interthecial strips.

Spores fasciculate in the ascus, long cylindric-fusoid, pale yellow to yellow-brown, 10–11-septate, with the fourth cell inflated, tapered at each end, somewhat curved, slightly constricted at the septa, with several droplets grouped at the cross-walls, six or seven septa below and two above the inflated cell, 140–155 × 5–6 μ.

Collection: *R1764a*, on Composite stem, Indian Henry's Hunting Ground, 5500 feet, August 3 (Type).

This collection might be placed in *Ophiobolus*, but the broad spores and their obvious relationship to the other species of *Leptosphaeria* of this region speak for its retention in this latter genus. The septation of the spores is similar to that of *Ophiobolus inflatus* Sacc. & Briard, but that species has shorter spores. Saccardo (**3**, vol. **9**: 931) gives the spores of *O. inflatus* as 100–140 × 3 μ, whereas Berlese (**1**, vol. **2**: 134) gives them as 100–120 × 2 μ, 9–10-

septate, and with the middle locule inflated. His figure (**1**, vol. **2**, *Pl. 161*, fig. 2) on the other hand, shows the fourth cell of a 10-septate spore inflated.

PLEOSPORA RAB.

The genus *Pleospora* is abundantly present on dead herbaceous stems both as to number of species and individuals, in the Mount Rainier area. There is very little similarity between the collections of *Pleospora* from Mount Rainier and those of the Wyoming mountains. The most striking difference is that of spore color. As has been mentioned (**6**), collections from higher elevations and

TABLE III

Coll. No.	Host	Spores	Asci	Perithecia
		Pleospora richtophensis var. *pallida*		
R1374	Ranunculus	26–32.5 × 11–14	85–95 × 26	300–400
R1926	Aster	35–44.5 × 14–17	125–195 × 26–28	300–400, T
		Pleospora rubicunda var. *americana*		
R1960	Pedicularis	30–38 × 11–12.5	140–160 × 21–26	250–300
R1951a	Potentilla	32–37 × 12.5–15	160–180 × 16–21	400
		Pleospora abscondita		
R1969a	Silene	37–48 × 9–11		

sub-alpine areas are usually darker red-brown in color than those from lower altitudes. This was true of most of the collections from Wyoming, especially those taken above 6000–8000 feet. The Mount Rainier collections are a striking exception to this rule, for practically every one of them had lighter, yellow-brown spores. The only collection (*R1919*) with reddish-brown spores was one of *P. herbarum* var. *occidentalis* which was taken from the highest elevation (7400 feet) of any of those made.

It is true that many of the Mount Rainier collections were made below 6000 feet, but most of them were made above 5000 feet and the ecologic conditions at this height are sub-alpine and similar to those at 8000–9000 feet in the Rocky mountains. Many collections

between 6000–7000 feet also showed yellow-brown spores. On the contrary the species with a dense stiff tomentum or setae upon the perithecia, which is also a characteristic of high altitude plants, were very abundant on Mount Rainier, but the spores in such perithecia were yellow-brown.

TABLE III includes those species placed in the *vulgaris* series, *i.e.*, those having spores without vertical septa in the end cells. All of these collections, except one (*R1374*) came from 6000 feet or above.

TABLE IV

SETOSE COLLECTIONS

		Pleospora ambigua		
R1424	Lupinus	19–23 × 9–11	105–140 × 16–17	150–300, T, s
R2338b	Valeriana	19–25 × 9–11	130–160 × 16–18	200–250, T, s
R1812a	Chrysanthemum	21–26 (35) × 9–11 (14)	70–110 × 16–26	250–400, T, s
R1601a	Lupinus	21.5–35 × 11–13	105–140 × 16–18	150–250, T, S
R1492d	Herb. stem	23–26 × 11–12.5	90–125 × 14–18	300, T
R1966	Artemisia	24–26.5 × 10.5–12.5	90–110 × 26–30	150–250, T, S
		Pleospora helvetica		
R1935	Arnica	23–26.5 × 12	125 × 14–16	200–300, T, S
R1613	Lupinus	23–28 × 11–13	150–160 × 17–18	200–300, T, S
R1671	Ligusticum	24–26 × 12.5–13	125–150 × 17–21	250–400, T, s
R1441	Hieracium?	25–28 × 12–13	110–140 × 17–18	250–350, T, s
R1672a	Valeriana	25–30 × 12.5–14	125–160 × 17–21	300–350, T, S
R1952b	Ligusticum	26–28 × 12–13	95–115 × 17–21	250–300, T, S
R1670	Aster	26–28 × 12.5–14	105–160 × 17–19	250–350, T, S
R1590	Valeriana	26–28 × 12.5–13	100–110 × 17–18	250–400, T, s
R1937a	Lupinus	26–30 × 11–14	105–125 × 14–18	400–500, T, S
R1673	Pedicularis	28–30 × 14–15	105 × 21	300, T, s
R1958	Achillea	28.5–32 × 12–14	90–115 × 17–19	200–300, T, S
		Pleospora comata		
R1969	Silene	43–57 × 19–23	160–180 × 40–45	200–300, T, S

Although *P. richtophensis,* with red-brown spores, was abundant in Wyoming, only two collections with similar spores were obtained west of the Rockies and both of these have the light brown color mentioned and have been placed in a var. *pallida* (**8**). Two collections with spores similar to the European *P. rubicunda* are also placed in a new variety, *americana* (FIGS. 17, 18) which was not found in Wyoming.

TABLE IV includes collections whose perithecia are clothed with a tomentum of stiff hairs or have setae penetrating the epidermis. This is the type of plant placed in *Pyrenophora* by many writers.

The spores of the Rainier collections are all of the herbarum type and the altitudinal distribution is over a wide range. The spores, however, were all yellow-brown. The relationships of this group have been treated previously (**8**).

TABLE V

HERBARUM SERIES

Coll. No.	Host	Spores	Asci	Perithecia
		Pleospora media var. *obtusa*		
R1939	Valeriana	18–28 × 11–13	125–175 × 14–21	200–300, t
R1669	Castilleja	21–28 × 10.5–12.5	90–100 × 20–21	200–250, t
		Pleospora herbarum		
R2189c	Sitanion	33–38 × 12–14	90–105 × 25–32	150
R2201	Phleum	35–42 × 15–17.5	132–160 × 35	200–300
		Pleospora herbarum var. *occidentalis*		
R1929	Artemisia	32–39 × 16–17	120–130 × 27–35	200–250, T
		Pleospora laxa		
R1951	Potentilla	52–58 × 23–25	125–160 × 50–60	200–250
		Pleospora asymmetrica		
R2187	Agrostis	43–47 × 16–26	200–250 × 50–60	200–300
R2289	Poa	49–61 × 19–24.5	160–175 × 40–43	200–300
R2188	Festuca	55–81 × 21–30	170–180 × 53	250–350
R1937b	Lupinus	55.5–72 × 19–30	175–200 × 40–50	300–500
R2204	Grass	61–82 × 26–35	200–210 × 70	300–400
R2200a	Muhlenbergia	63–70 × 26–30	170–200 × 55–70	300–350
		Pleospora rainierensis		
R2209	Muhlenbergia	53–70 × 22–26	195–230 × 53–60	250–350
R1746d	Composite	58–68 × 32–34	200–350 × 20–25	

TABLE V includes those collections with a *herbarum* type spore, but smooth perithecia. The *P. media–P. herbarum* group which was so abundant in Wyoming and showed the characteristic red-brown spores of higher altitudes, is represented from Rainier by only five collections, all of which, except one (*R1929*), have yellow-

brown spores. *P. laxa* is a yellow-spored species originally described from Montana. *P. asymmetrica* appears to be a yellow-brown counterpart of *P. montana*, which was described from Wyoming and *P. rainierensis* was described as new (**10**) from this area.

PLEOSPORA RICHTOPHENSIS var. PALLIDA Wehm.

This variety and these collections have been previously described (**8**).

Collections: *R1374*, on *Ranunculus* sp., Summit Pass, Blue Mountains, Austin, Oregon, 4300 feet, June 17; and *1746a*, on *Compositae*, Indian Henry's Hunting Ground, 5500 feet, August 3.

These two collections were made some distance apart and the spore sizes (see TABLE III) are quite distinct, but they both lie within the range of *P. richtophensis*, differing in the lighter spore color.

PLEOSPORA RUBICUNDA Niessl var. **americana** var. nov. FIGS. 17, 18

Perithecia ut in specie. Maculae discolores caulium pallide vinaceae vel rubrobrunneae. Sporae 30–38 μ longae, 11–15 μ crassae, pallide luteo-brunneae, ad septa paulum vel haud constrictae; septatione irregulari, interdum asymmetrica, primariis et secondariis exacte 7, tertiariis successive productis 4 vel minus quam 4 ergo inter 7 et 11.

Specimen typicum legit Wehmeyer (n. *R1960*), in caulibus *Pedicularis latifoliae*, ad "Berkeley Park," alt. 6000 ped., 17 Aug. 1948.

Perithecia as in species, discoloration of the host pinkish-purple or dark reddish-brown; spores 30–38 × 11–15 μ, light yellow-brown, slightly or not at all constricted, septation irregular with tertiary septa successively laid down and spores, therefore, from 7–11-septate, sometimes asymmetrically so, with three septa above and five below the central primary septum.

Collections: *R1960*, on *Pedicularis latifolia*, Berkeley Park, 6000 feet, August 17 (Type); and *R1951a*, on *Potentilla flabbelifolia*, Yakima Park, 6400 feet, August 18.

The *P. rubicunda* of Europe is found on purplish red spots on stems and has regularly 11-septate, rather dark red-brown spores. These two collections, for which this variety is erected, have spores with the same form as those of *P. rubicunda* but which may be

slightly more strongly constricted and a lighter, yellow-brown. Their septation arises in the same way as in the species, *i.e.*, by the formation of tertiary *vulgaris*-type septa in the four central cells of a 7-septate spore, but these septa are formed tardily and in a successive manner with the result that the spores may be from 7–11-septate or even asymmetrically septate because of the development of septa in only one end of the spore.

PLEOSPORA ABSCONDITA Sacc. & Roum.

Perithecia and asci not seen.

Spores long-fusoid, yellow-brown to dark yellow-brown, 10–12- or sometimes 14-septate, straight or slightly inequilateral, symmetric or slightly asymmetric, constricted at the primary septum only, ends taper-pointed, 37–48 × 9–11 μ. The spore is basically with three or rarely four septa above the primary central septum and four or rarely five septa below it. Tertiary *vulgaris*-type septa may arise in either two or four of the central cells. Vertical walls may occur in any of the cells except the end cells.

Collection: *R1969a*, on *Silene Macounii*, Frozen Lake, 6700 feet, August 17.

Only free spores on the surface of the epidermis, in the mount, were seen of this species. It and several other collections with variable septation in the spores were previously placed in *P. abscondita* (**11**), but this epithet is used provisionally.

PLEOSPORA AMBIGUA (Berl. & Bres.) Wehm. FIG. 20

Perithecia 150–400 μ in diameter, scattered, immersed, more or less densely tomentose with stiff brown hairs which may become seta-like and penetrate the overlying epidermis.

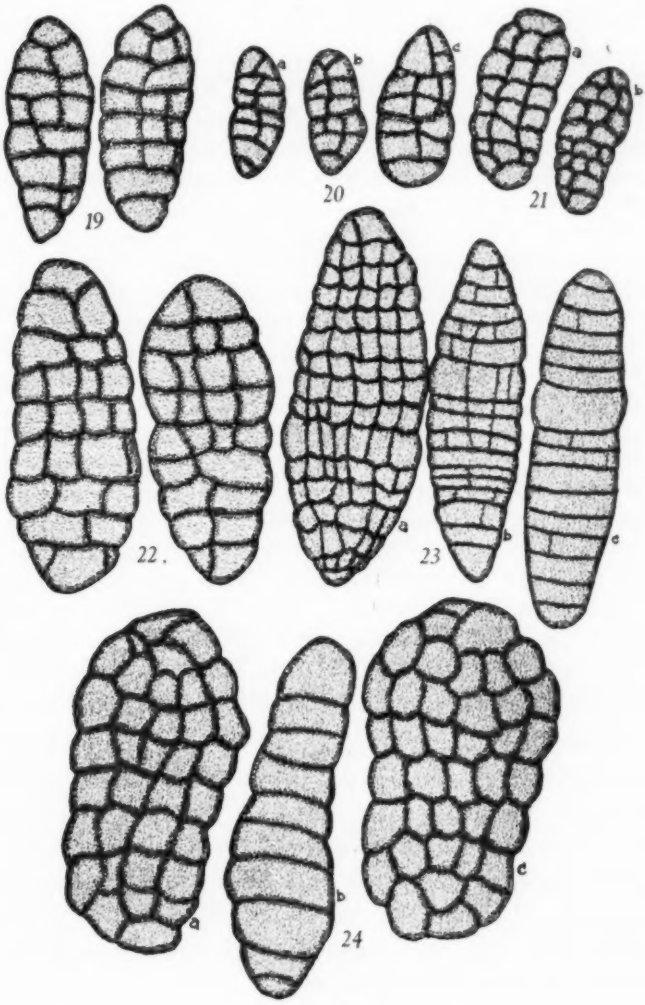
Asci clavate, with a thickened wall and a claw-like base, 90–160 × 16–26(–30) μ.

Spores biseriate, fusoid- to oblong-ellipsoid, 5–7-septate, yellow-brown, often asymmetric with one end rounded, the other bluntly tapered, often with a vertical wall in the end cells, and one vertical wall in the central cells, 19–26 × 9–12.5 μ.

Collections: *R1424*, on *Lupinus subalpinus*, Reflection Lake, 4865 feet, July 5; *R1492d*, on herbaceous stem, Lake Louise, 4600 feet, July 13; *R1601a*, on *Lupinus Lyallii*, Mazama Ridge, 5700 feet, July 21; *R1812a*, on *Chrysanthemum leucanthemum*, Longmire Hot Springs, 2700 feet, July 9; *R1966*, on *Artemisia taco-*

mensis, Berkeley Park, 6000 feet, August 17; and *R2338b*, on *Valeriana sitchensis*, Mazama Ridge, 5700 feet, July 21.

The name *P. ambigua* was used by the writer (**9**) for a group of collections with spores like *P. media* but with setose-tomentose



FIGS. 19–24.

perithecia, which is common in the European Alps and also found in our western mountains. These Mount Rainier collections are all with the yellow-brown spores of the variety *typica* as used in the paper mentioned.

PLEOSPORA HELVETICA Niessl. FIG. 21

Perithecia 200–500 μ in diameter, rather thickly scattered, usually somewhat depressed-spheric, clothed with a dense tomentum of stiff brown hairs which often become spine-like and project through the epidermis.

Asci rather long-clavate, with a thickened wall and claw-like base, 100–160 × 16–21 μ.

Spores biseriate to overlapping uniseriate, fusoid- or mostly oblong-ellipsoid, yellow-brown, mostly 7-septate, somewhat asymmetric, slightly inequilateral, ends bluntly rounded, usually with two or more vertical septa in face view in the central cells, 23–32 × 11–15 μ.

Collections: *R1441*, on Composite (*Hieracium*), Nisqually Glacier, 4000 feet, July 8; *R1590*, on *Valeriana sitchensis*, Mazama Ridge, 6000 feet, July 21; *R1613*, on *Lupinus subalpinus*, Van Trump Park, 5600 feet, July 25; *R1670*, on *Aster foliaceus*, Treeline Ridge, 6500 feet, July 30; *R1671*, on *Ligusticum purpureum*, Treeline Ridge, 6500 feet, July 30; *R1672a*, on *Valeriana sitchensis*, Treeline Ridge, 6500 feet, July 30; *R1673*, on *Pedicularis contorta*, Treeline Ridge, 6500 feet, July 30; *R1935*, on *Arnica Parryi*, Dege Peak Trail, 6900 feet, August 19; *R1937a*, on *Lupinus volcanicus*, Dege Peak Trail, 6800 feet, August 19; *R1952b*, on *Ligusticum purpureum*, Yakima Park, 6400 feet, August 18; and *R1958*, on *Achillea Millefolium*, Berkeley Park, 5600 feet, August 15.

These collections fall in this species as previously used (**9**) for those similar to *P. ambigua* but with somewhat larger spores having mostly two rather than one vertical septum showing in face view. The spores in these collections were all yellow brown and would correspond to those of *P. herbarum* which occur in smooth perithecia. The stiff tomentum on the perithecia is usually visible with a hand lens and through the epidermis. Most of the collections are from higher altitudes.

PLEOSPORA COMATA Niessl

Perithecia 200–300 μ in diameter, scattered, globose or somewhat depressed, clothed with a tomentum of stiff brown hairs, often penetrating the epidermis.

Asci clavate, apical wall thickened, 160–180 × 40–45 μ.

Spores overlapping biseriate, oblong-ellipsoid, yellow-brown, 7–8-septate, asymmetric, mostly straight, constricted at the septa, 43–57 × 19–23 μ.

Collections: *R1969,* on *Silene Macounii,* Frozen Lake, 6700 feet, August 17.

The tomentose-setose character of the perithecia (**9**) is the same in this collection as in the two previous species but the spores are larger and often show an eighth septum in the lower portion. The spores, however, are yellow-brown.

PLEOSPORA MEDIA var. OBTUSA Wehm.

Perithecia 200–300 μ in diameter, smooth, globose, scattered, sometimes with a slight tomentum.

Asci clavate, 90–175 × 14–21 μ, apical wall somewhat thickened.

Spores biseriate, mostly oblong-ellipsoid, 5- to sometimes 7-septate, mostly symmetric, inequilateral or curved, constricted at the septa, with one vertical wall in face view, often extending through the end cells, 18–28 × 10–15 μ.

Collections: *R1669,* on *Castilleja oreophila,* Treeline Ridge, 6500 feet, July 30; *R1939,* on *Valeriana sitchensis,* Dege Peak Trail, 6800 feet, August 19.

These collections have spores like those of *P. ambigua,* but the perithecia are smooth. In some cases, as in No. *1669,* there is a slight basal tomentum and such collections grade off into *P. ambigua.* Even though found at high elevations these spores are yellow-brown.

PLEOSPORA HERBARUM (Fr.) Rab. FIG. 19

Two collections with yellow-brown spores are somewhat doubtfully placed in this ubiquitous species; they are:

Collections: *2189c,* on *Sitanion Hystrix,* Berkeley Park, 6000 feet, August 17; and *R2201,* on *Phleum alpinum,* Van Trump Park, 5800 feet, July 26.

Although from high elevations, both these collections show yellow-brown spores. In No. *2189c,* many of the spores lack vertical walls in the end cells and approach the spores of *P. punctata* in form.

PLEOSPORA HERBARUM var. OCCIDENTALIS Wehm.

Collection: *R1929,* on *Artemisia tecomensis,* Burroughs Mt., 7400 feet, August 20.

This collection is typical of the variety as previously described (**6**). The spores are light but definitely reddish-brown. The perithecia show some stiff tomentum but not sufficient to place them in *P. Tragacanthae* Rab. It is interesting to note that this, the only collection with red-brown spores, came from the highest elevation of any of those made on Mount Rainier.

PLEOSPORA LAXA Ell. & Holw. FIG. 22

Perithecia 200–250 μ in diameter, thickly scattered, pustulate-erumpent, smooth; ostiole papillate to conic; walls 30–50 μ thick, parenchymatic.

Asci stout-clavate, apical wall thickened, 125–160 × 50–60 μ.

Spores overlapping biseriate, oblong-ellipsoid, yellow-brown, mostly 8-, sometimes 7-septate, straight, asymmetric, constricted slightly at the septa, ends rounded, 52–58 × 23–25 μ.

Collection: *R1951,* on *Potentilla flabellifolia,* Yakima Park, 6400 feet, August 18.

This collection differs from the type collection in not being on a grass and in having slightly larger spores with more rounded ends and less strongly constricted at the central septum, but these differences do not seem large enough to erect a new species when only two collections are known.

PLEOSPORA ASYMMETRICA Wehm.

This species was described (**10**) from the Rainier collections listed. The spores have the same general type of septation as do those of *P. montana,* which was described from high altitudes in Wyoming. The spores of *P. asymmetrica* have a more irregular septation and are yellow- rather than red-brown. The fact that

one collection of *P. asymmetrica* occurs on *Lupinus*, as have all collections of *P. montana*, and the other three occur on grasses, suggests that there may be two species included here, but with the few collections available no such distinctions could be made.

Collections: *R1937b*, on *Lupinus volcanicus*, Dege Peak Trail, 6800 feet, August 19; *R2187*, on *Agrostis* sp., Yakima Park, 6400 feet, August 18; *R2188*, on *Festuca rubra*, Berkeley Park, 6000 feet, August 17; *R2200a*, on *Muhlenbergia filiformis*, Indian Henry's Hunting Ground, 5500 feet, August 2; *R2204*, on grass, Van Trump Park, 5800 feet, July 26; *R2289a*, on *Poa* sp., Mazama Ridge, 5500 feet, July 21.

PLEOSPORA RAINIERENSIS Wehm.

This species has also been described from the following collections (**10**). It has a peculiar type of septation in which the chief central constriction is at the septum above the central primary one. It was found on both a grass and a composite stem at the same locality. The septation of the spores is similar to that found in *Clathrospora Cookei*, described in this paper.

Collections: *R1746d*, on Composite stem, Indian Henry's Hunting Ground, 5500 feet, August 3; *R2209*, on *Muhlenbergia filiformis*, Indian Henry's Hunting Ground, 5300 feet.

CLATHROSPORA RAB.

It has been the writer's experience that the species of *Pleospora* with flattened "clathrate" spores showing no vertical septa in edge view are a quite distinct group and worthy of generic rank. They are, therefore, so considered here. The genus *Clathrospora* itself is made up of two distinct groups. In one group of species the spores are 3–5-septate, have only one vertical septum in face view, have more or less tomentose perithecia and occur on herbaceous stems other than grasses, sedges or rushes. The second group have larger spores, of a lighter color, show nine to fifteen transverse and two to five vertical septa in face view, have smooth perithecia and occur only on sedges, rushes, or grasses.

The occurrences of *Clathrospora* are conspicuously few on Mount Rainier. Whereas the species *Clathrospora* (*Pleospora*) *permunda*

(Cke.) Sacc. was collected twenty-one times in Wyoming, only one collection was obtained on Mount Rainier.

The remaining three collections of *Clathrospora* from Rainier were all of the second group mentioned above and were on sedges or grasses and all represented new species.

CLATHROSPORA (*Pleospora*) PERMUNDA (Cke.) Berl.

Perithecia 250–400 μ in diameter, scattered, depressed-globose, becoming pezizoid-collapsed, with a radiating tomentum of coarse, stiff, brown hairs.

Asci 90–100 × 31–35 μ, broad-clavate, wall somewhat thickened.

Spores biseriate, clathrate, broad fusoid-ellipsoid in face view, fusoid-cylindric in edge view, yellow-brown, 3-septate in face and edge view, one vertical septum in the two central cells in face view, straight, symmetric, constricted at the septa, 26–38 × 14–17 × 9–10 μ.

Collection: *R1952a*, on *Ligusticum purpureum*, Yakima Park, 6400 feet, August 18. This collection is typical of the species but with rather large, light-colored spores.

Clathrospora Simmonsii sp. nov. FIG. 24

Perithecia globosa vel elongata, applanata, 300–400 μ longa, 100–200 μ crassa, 100–150 μ alta, dense sed singulatim dispersa, in superficie ut maculae minutae punctatae vel elongatae nigricantes visa; perietibus 30–35 μ crassis, nigris, parenchymatosis. Asci 125–160 μ longi, 35–55 μ crassi, clavati, basi unguiculiformes, membrana vix incrassati. Sporae oblonge ellipsoideae, lateraliter compressae, clathratae, 52–62 μ longae, 26–35 μ latae, 13–18 μ crassae, imbricatae, biseriatae, rectae vel paululo inequilaterales et asymmetricae, parte supra septum centrale latiore et brevior quam part inferiore, pallide luteo-brunneae vel luteae, 7-9-septatae, saepissime cum 7 septis rectis et utrinque septo uno Y-formi praeditae, ad omnia septa constrictae, aspectu frontali 3- vel 5- verticaliter septatae, aspectu laterali verticaliter aseptatae.

Specimen typicum legit Wehmeyer (*R1930*) in culmis *Caricis oblatae*, prope "Burrough's Mt.," alt. 7400 ped., 20 Aug., 1948.

Perithecia sometimes globose, 150–200 μ in diameter, sometimes elongate, flattened, 300–400 × 100–200 × 100–150 μ, thickly scattered, beneath the epidermis, appearing as minute rounded dots or as elongate blackened spots; walls 30–35 μ thick, of very coarse, black parenchyma.

Asci broad-clavate, wall not, or only slightly, thickened, base claw-like, 125–160 × 35–55 μ.

Spores overlapping biseriate, light yellow-brown to yellow-

brown, oblong-ovoid, flattened, clathrate, somewhat cylindric-clavate in edge view, 7–9-septate, usually with seven distinct septa and a "Y" shaped septum at each end, straight or slightly inequilateral, mostly somewhat asymmetric, broader and shorter above, constricted at all of the septa, with three to five vertical septa in face view and none in edge view, 52–62 × 26–35 × 13–18 μ.

Collections: *R1930* (Type) and *R1931*, on *Carex oblata*, Burrough's Mt., 7400 feet, August 20.

Both collections were made on the same host in the same general area. The species belongs to the *Cl. Elymae* group. There seem to be a number of species determined under this name and they appear to be limited to a genus or even species of host in some cases. *Clathrospora juncicola* E. & E. seems to be closest to this collection in spore morphology, but the spores of its type collection (N.Y.B.G., Ellis coll. No. *75*) are only 32–35 × 13–18 × 9–12 μ.

Clathrospora Cookei sp. nov. FIG. 23

Perithecia 250–400 μ diametro, oblate globosa, dispersa, in contextu folii immersa et per rimam epidermatis erumpentia; pariete 30–40 μ crasso, atro, parenchymatoso. Asci 192–270 μ longi, 36–60 μ crassi, longe clavati, membrana apicali crassa, basi unguiculiformes. Sporae luteo-brunneae, clathratae, 50–70 μ longae, 18–26 μ latae, 14–18 μ crassae, biseriatae vel oblique uniseriatae, rectae, asymmetricae, ad septa constrictae, plerumque 15-septatae et cellularum zona lata trans median partem latissimam praeditae; septis supra zonam 5, infra eam 8; aspectu frontali elliptice fusoidales et 3- vel 5- verticaliter septatae, aspectu laterali fusoideae vel cylindrice fusoideae, interdum obscure verticaliter pauciseptatae vel septis verticalibus multis praeditae.

Specimen typicum in caulibus *Stipae californicae*, prope locum "Horse Camp" dictum, in monte Shasta, California, alt. 8000 ped., 27 Juni, 1946, leg. W. B. Cooke (n. *18095*).

Perithecia 250–400 μ in diameter, somewhat flattened-spheric, rather widely scattered, sunken in the leaf tissue then erumpent through a slit in this tissue; ostiole not obvious; wall 30–40 μ thick, of black parenchyma.

Asci long-clavate, with a thickened apical wall and a claw-like base, 195–270 × 35–60 μ.

Spores biseriate to oblique uniseriate, clathrate, flattened, fusoid-ellipsoid in face view, fusoid to cylindric-fusoid in edge view, yellow brown, constricted at the septa in face view, straight, asymmetric, mostly 15-septate, with three to five vertical septa in face view; in edge view sometimes a very few and very faint septa, at other times with rather numerous faint septa, with a broad band of large

cells across the broadest part of the spore; five septa above and eight below this band; 50–70 × 18–26 × 14–18 μ.

Collections: On *Stipa californica*, Horse Camp, Mt. Shasta, California, 8000 feet, June 27, 1946 (Wm. B. Cooke No. *18095*) (Type); *R2209f*, on *Muhlenbergia filiformis*, Indian Henry's Hunting Ground, 5300 feet, July 18.

This species was first sent to the writer by W. B. Cooke, from Mt. Shasta, and later turned up in the Mount Rainier collections. In both cases the perithecia were scattered and associated with other pyrenomycetes. It is a most interesting type, and the only one which shows an intermediate condition between the genera *Pleospora* and *Clathrospora*. The spores are definitely flattened but occasionally they show faint vertical septa in edge view. The spores of the Mount Rainier collection, on *Muhlenbergia*, have a form which, in edge view, is cylindric, with rounded ends, and sometimes inequilateral and the vertical septa are few or seldom seen, whereas the collection on *Stipa*, from Mt. Shasta, has spores which are more fusoid in edge view and there are usually quite a few faint vertical septa visible. If further collections show these characters to be correlated with the host they may prove to be of varietal rank.

The band of longer cells across the broadest portion of the spore is characteristic and gives it an appearance similar to *Pleospora rainierensis* which, in fact, occurs upon the same stems in collection No. *R2209*.

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EXPLANATION OF FIGURES

FIGS. 1–18. 1. Spores of *Leptosphaeria Typharum* (Desm.) Karst. sensu Berl., from collections No. *R2209c* (a), *R2200* (b), *R2187b* (c) and *R2192* (d). 2. Spore from collection No. *R2213*, of *Leptosphaeria vagans* Karst. sensu Berl. 3. Spores of *Leptosphaeria culmifraga* (Fr.) Ces. & de Not., from collections No. *R2185* (a), *R2188a* (b) and *R2207* (c). 4. Spores of *Leptosphaeria elongata* sp. nov., from collections No. *R2195* (a) and *R2214* (b). 5. Spores of *Leptosphaeria filiformis* sp. nov., from collection No. *R1746a*. 6. Spores of *Leptosphaeria Niessleana* Rab.; two from collection No. *R1441a* (a) and one from No. *R1604*. 7. Spores from collection No. *R1620* of *Leptosphaeria Bupleuri* Syd. 8. Spores from collection No. *R1746b* of *Leptosphaeria Baldingerae* Fautr. & Lamb. 9. Spores of *Leptosphaeria tenera* Ell., from collections No. *R2197* (a) and *R1439* (b). 10. Spores from collection No. *R1456* of *Leptosphaeria norvegica* Rostr. 11. Spores of *Leptosphaeria Salsolae* Hollos, from collections No. *R1947* (a) and *R1492c* (b). 12. Spores of *Leptosphaeria Erigerontis* Berl., from collections No. *R1957* (a), *R1942* (b) and *R1941* (c). 13. Spores of *Leptosphaeria agnita* (Desm.) Ces. & de Not., from collections No. *R1425* (a) and *R2343* (b). 14. Spores of *Leptosphaeria Drabae* (Nyl.) Karst., from collections No. *R1493b* (a) and *R1747* (b). 15. Spores from collection No. *R1603* of *Leptosphaeria multiseptata* Wint. 16. Spores of *Leptosphaeria asparagina* Karst., one from collection No. *R1574* and three from *R2191*. 17. Spores from collection No. *R1960* of *Pleospora rubicunda* Niessl var. *americana* var. nov. 18. Spores from collections No. *R1951a* of *Pleospora rubicunda* Niessl var. *americana* var. nov.

FIGS. 19–24. 19. Spores of collection No. *R2189c* of *Pleospora herbarum* (Fr.) Rab. 20. Spores of *Pleospora ambigua* (Berl. & Bres.) Wehm., from collections No. *R1424* (a), *R1601a* (b) and *R1966* (c). 21. Spores of *Pleospora helvetica* Niessl, from collections No. *R1672a* (a) and *R1935* (b). 22. Spores from collection No. *R1951* of *Pleospora laxa* Ell. & Holw. 23. Spores of *Clathrospora Cookei* sp. nov., from the type collection (Wm. B. Cooke, No. *18095*), in face (a) and edge (b) view, and from No. *R2209f*, in edge view (c). 24. Spores of *Clathrospora Simmonsii* from the type collection (*R1930*), in face (a) and edge (b) view, and from No. *R1931*, in face view (c).

THE GENUS AURICULARIA

BERNARD LOWY

(WITH 15 FIGURES)

The morphology of the genus *Auricularia* was discussed in an earlier paper (**9**) and it is the purpose of the present report to supplement this with an account of the species from a taxonomic and nomenclatural point of view. All combinations and citations which have appeared in the literature, so far as I have been able to discover, are here accounted for either as synonyms, species inquirendae, species excludendae or nomina nuda, each name being assigned its most suitable category in accordance with the evidence available.

In order to conserve space, extended comments concerning the species inquirendae and species excludendae are omitted, but are included in the text of the author's (**8**) doctoral thesis on deposit in the library of the State University of Iowa. For a similar reason, only a partial list of illustrations and exsiccati is offered.

Distribution is indicated on world maps, thus allowing geographical ranges of the species to be compared with facility. Since more than two thousand collections from tropical, subtropical and temperate regions were examined in the course of this study, it was not practicable to indicate each collection, but all localities from which specimens were examined are shown.

Most of the species are illustrated by photographs in toto and in section as well as by camera lucida drawings of basidia and spores. Photographs of mature fruiting bodies have been selected following the examination of large numbers of specimens and are intended to illustrate the species in what I consider to be their typical form. Although it should not be assumed that identification of a specimen will be possible in every case by referring to the photographs alone, it is safe to say that *A. delicata* with its merulioid hymenium and *A. Emini* with its long hairs cannot be mis-

taken for any other species. Photographs of other species may be suggestive and helpful in making a tentative diagnosis, but sections should always be made whenever the determination of the specimen is in doubt.

In order to facilitate the identification of species by the use of freehand sections, a series of outline drawings has been included, representing sections through the fruiting body cut on a plane perpendicular to the superior surface. These schematic figures are based upon camera lucida drawings and should be used in conjunction with the key to the species which appeared in a paper previously published (**9**).

I wish to express my gratitude to Professor G. W. Martin of the State University of Iowa for his guidance throughout the course of this study. My thanks are also due Dr. S. J. P. Chilton, Head of the Department of Botany, Bacteriology and Plant Pathology of Louisiana State University, for making funds available for the illustration of this paper.

DESCRIPTION OF THE GENUS

AURICULARIA Bulliard ex Mérat, Nouv. Fl. Env. Paris ed. 2. **1**: 33. 1821.

Fructification when fresh rubbery-gelatinous, varying from resupinate with free margins to substipitate or occasionally stipitate; saprobic; solitary or gregarious to imbricate-caespitose; mature specimens 1–2 mm. in thickness, mostly from 5–6 mm. to 8–10 cm. or more in width; when dry, thin, translucent to opaque, horny and brittle; superior surface pilose, hairs 65–500 μ or more in length; inferior surface bearing the hymenium, which is externally glabrous to pruinose, often with venulose folds; color pallid or rosy to dark brown or black; sections perpendicular to superior surface showing hyphal organization of characteristic morphology with discernible zonation; hymenial layer dense, basidia cylindrical to clavate, transversely 3-septate, giving rise to slender epibasidia terminating in sterigmata which penetrate the tough hymenial membrane; paraphyses branched, slender, usually strongly metamorphosed; basidiospores white to ochraceous in mass, cylindrical to allantoid, germinating by a germ tube, by the production of conidia or by repetition.

DESCRIPTION OF SPECIES

1. AURICULARIA AURICULA (Hook.) Underw.; Barrett, Mycologia **2**: 12. 1910. FIGS. 1, 4A, B, 11C, 13A, 15 (1–7).

Tremella auricula L. ex Hook. Fl. Scot. **2**: 32. 1821.

Peziza auricula L. ex Mérat, Nouv. Fl. ed. 2. **1**: 26. 1821.

Gyraria auricularis S. F. Gray, Nat. Arr. Brit. Pl. **1**: 594. 1821.

Auricularia Sambuci Pers. Myc. Eur. **1**: 97. 1822.

Tremella auricula-judae Bull. ex Schw. Schrift. Naturf. Ges. Leipzig **1**: 115. 1822.

Tremella auricula-judae Bull. ex Schw. Schrift. Naturf. Ges. Leipzig **1**: 115. 1822.

? *Auricularia Judae* Wahlenb. Fl. Suec. **2**: 993. 1826.

Auricularia judae Link, Handb. **3**: 338. 1833.

Auricula[ria] judae Secr. Mycog. Suisse **3**: 229. 1833 (corrected in index).

Exidia auricula Fries ex Wallr. Fl. Crypt. Germ. **2**: 559. 1833.

Hirneola auricula-judae Berk. Outl. Brit. Fung. 298. 1860.

Hirneola auricula Fries ex H. Karst. Deutsche Fl. 93. 1880.

Auricularia Sambucina Mart. ex Winter & Demet. Hedwigia **24**: 185. 1885.

Auricularia Auricula-Judae (Fries) Schroet. Krypt. Fl. Schles. **3**: 386. 1888.

Auricula Judae Kuntze, Rev. Gen. **3**: 884. 1891.

Hirneola Auricula (L.) Karst. Fl. Deutschl. 93. 1880 (cited by Bresadola, Icones Mycol. **23**. pl. 1109. 1932).

Auricularia auricularis (S. F. Gray) Martin, Am. Midl. Nat. **30**: 81. 1943.

Fructification tough-gelatinous when fresh, commonly solitary, occasionally gregarious or caespitose becoming variously convoluted upon maturity; yellow-brown to reddish-brown when moist; sessile to substipitate, up to 12 cm. broad. 0.8–1.2 mm. thick.

Zona pilosa: Hairs 85–100 μ long, 5–6 μ in diameter, hyaline, without central strand, rounded at tips, not in dense tufts.

Zona compacta: 65–75 μ wide, hyphae densely compacted, individual elements not distinguishable.

Zona subcompacta superioris: 115–130 μ wide, hyphae about 2 μ in diameter, forming a dense network giving the zone a somewhat coarsely granular appearance.

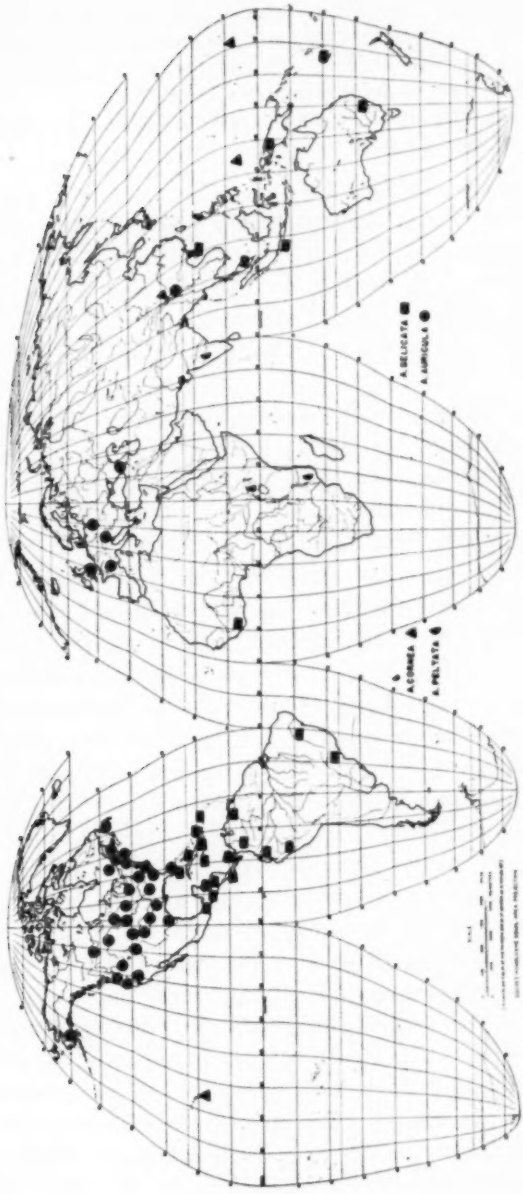

FIG. 1. Distribution of *A. cornea*, *A. delicata*, *A. auricula*, *A. peltata*.

Zona intermedia: 285–300 μ wide, hyphae 1.5–2 μ in diameter, mostly horizontal in orientation, with numerous small interstices.
Zona subcompacta inferioris: 100–120 μ wide, hyphae about 2.5 μ in diameter, forming a densely compact layer.
Hymenium: about 150 μ thick; basidia 50–60 × 5–6 μ, cylindrical; spores allantoid, 13–15 × 5–6 μ.

TYPE LOCALITY: Europe.

DISTRIBUTION: Mostly in temperate regions of North America and Europe (FIG. 1).

ILLUSTRATIONS: P. A. Micheli, Nov. Pl. Gen. *pl. 66, fig. 1.* 1729. T. J. Hussey, Ill. Brit. Myc. *pl. 53.* 1847–55. M. J. Berkeley, Outl. *pl. 18, fig. 7.* 1860. C. G. Lloyd, Myc. Writ. **5**: *783. fig. 1175.* 1918.

EXSICCATI: Rabenhorst, Fungi europaei *2308* [as *Hirneola auricula Judae* (Linn. Sp.)]. M. C. Cooke, Fungi Britanici exsiccati *517* (as *Hirneola auricula Judae* Fr.). H. W. Ravenel, Fungi Americani Exsiccati *463.* Ellis, North American Fungi *519.* Rick, Fungi Austro-Americani *137.*

This species, commonly called the "Jew's ear" because of its fancied resemblance to a human ear, is without doubt the species most abundantly found throughout the temperate regions of the world. In connection with the common name of this species it is interesting to note that Lloyd (**4**) proposed the substitution of the name *A. auricula,* a combination made by Underwood in 1902, to replace the name *A. Judae* Kuntze 1891. Lloyd explains his reason in the following way: "Underwood, I believe, was the first modern juggler to use *A. auricula* . . . although Underwood would probably not have known the Jew's ear from a calves' liver. It is needless to say we are not making the change on account of Underwood's juggling, but *Auricularia auricula-Judae* is cumbersome and in addition is a slander on the Jews." The name *A. auricula* (Hook.) Underw., adopted in this paper, is valid under the present rules.

This species has been frequently reported from the tropics, but of the specimens which I have examined none could be assigned here. Superficially, *A. auricula* approaches *A. fuscosuccinea* in color and texture and the latter may be confused with it if only external features are considered. There are minor differences in spore and basidial size but these structures are not sufficiently dis-

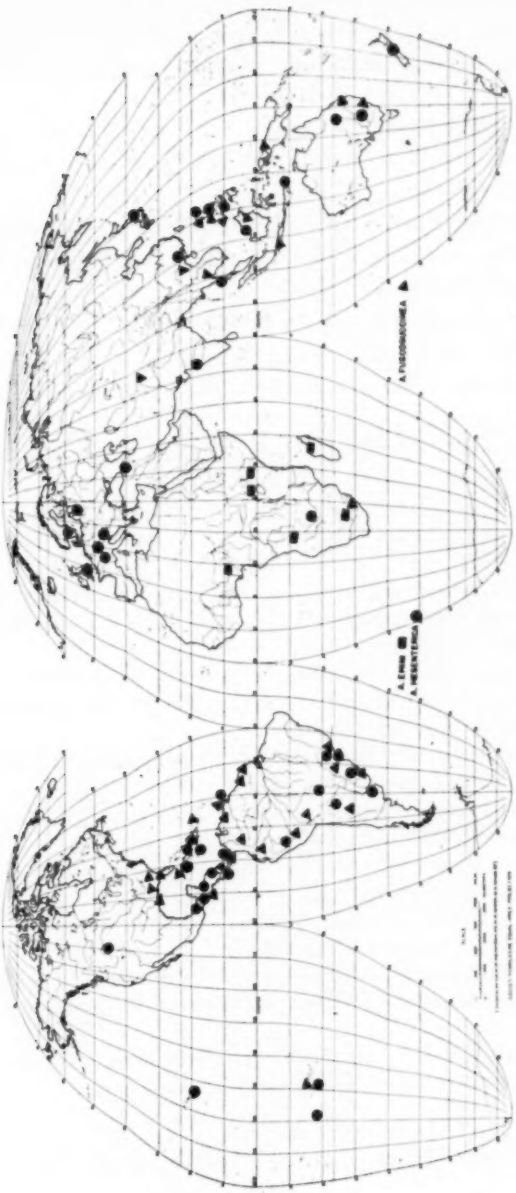

FIG. 2. Distribution of *A. Emini*, *A. fuscosuccinea*, *A. mesenterica*.

tinctive to be used as reliable criteria. *A. cornea* may also be confused with *A. auricula*, but aside from internal differences, the former is more pilose and tends to be more gregarious in habit.

2. AURICULARIA CORNEA (Ehrenb. ex Fries) Ehrenb. ex Endl. Wiener Mus. Nat. Ann. **1**: 146. 1836. FIGS. 1, 4C, D, 12D, 13B, 15 (8–14).

Exidia cornea Ehrenb. ex Fries, Syst. Myc. **2**: 222. 1822.

Auricularia ampla Pers. in Gaudichaud, Bot. Freycinet Voyage autor du Monde 177. 1827.

Tremella cornea (Ehrenb. ex Fries) Spreng. Linn. Syst. Veg. 16 ed. **4**: 535. 1827.

Exidia ampla (Pers.) Lév. Ann. Sci. Nat. Bot. III. **5**: 159. 1846.

Hirneola ampla (Pers.) Fries, K. Vetensk. Akad. Handl. **1849**: 146. 1849.

Hirneola cornea (Ehrenb. ex Fries) Fries, K. Vetensk. Akad. Handl. **1848**: 146. 1849.

Fructification solitary to gregarious, inferior surface cupulate, shallowly venulose, substipitate to sessile, largest specimens about 15 cm. broad, 0.8–1 mm. thick.

Zona pilosa: Hairs 180–200 μ long, 5–7 μ in diameter, without central strand, rounded at tips; individual hairs clearly distinguishable, tending to aggregate in tufts.

Zona compacta: 70–80 μ wide, densely compacted, containing brownish pigment, individual hyphae not distinguishable.

Zona subcompacta superioris: 20–30 μ wide, hyphae oriented mostly perpendicular with the surface.

Zona laxa superioris: 40–50 μ wide, hyphae 5–6 μ in diameter, merging abruptly with the medulla.

Medulla: 570–600 μ wide, hyphae 4–5 μ in diameter, mostly parallel with the surface, not compact.

Zona laxa inferioris: 30–40 μ wide, hyphae 4–6 μ in diameter.

Zona subcompacta inferioris: 70–80 μ wide, hyphae 4–5 μ in diameter.

Hymenium: 80–90 μ wide, very compact; basidia clavate, 45–55 $\times$ 4–5 μ, 3-septate; spores allantoid, 14–16 $\times$ 5–6 μ.

TYPE LOCALITY: Marianna Islands.

DISTRIBUTION: China, Hawaii, Marshall Islands, Palau Islands (FIG. 1).

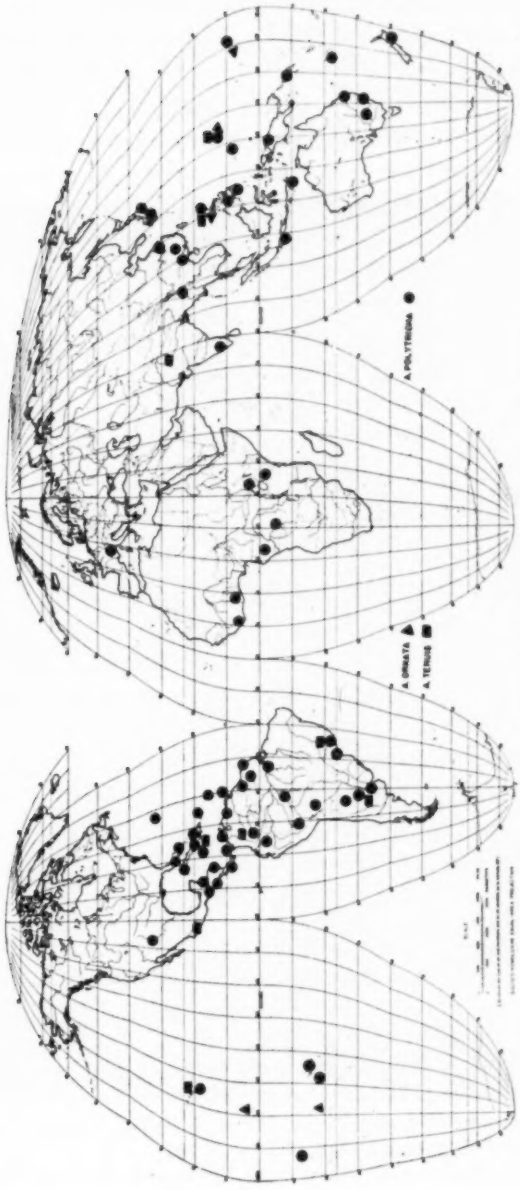

FIG. 3. Distribution of *A. ornata*, *A. polytricha*, *A. tenuis*.

EXSICCATI: Sydow, Fungi exotici exsiccati *322*.

Through the kindness of Dr. D. P. Rogers of the New York Botanical Garden, who collected this species in the Marshall Islands, I have had the opportunity of examining his personal collection. Rogers (**14**) states that the question of the distinctness of *A. cornea* and of *A. auricula* has been doubted, but in his opinion, on the basis of the examination of living material, they are readily distinguishable. I have not seen *A. cornea* in the living state, but on the evidence of internal morphology I am convinced that these species are distinct. Rogers also reports that *A. cornea* is regarded as good food in the Hawaiian Islands but not in the Marshalls. A considerable trade once flourished in the export of this fungus to China where it is still used as a common article of diet.

3. AURICULARIA DELICATA (Fr.) Henn. Engl. Jahr. **17**: 493. 1893.
FIGS. 1, 5A, B, 12B, 13C, 15(15–22).

Laschia delicata Fries, Linnaea **5**: 553. 1830.
Laschia tremellosa Fries, Summa Veg. Scand. 325. 1849.
Auricula delicata (Fries) Kuntze, Rev. Gen. **3**: 446. 1898.
Auricula tremellosa (Fries) Kuntze, Rev. Gen. **3**: 446. 1898.
Auricularia tremellosa (Fries) Pat. Jour. de Bot. **1**: 226. 1887.
Auricularia Moelleri Lloyd, Myc. Writ. **5**: 784. 1918.
Auricularia Hunteri Lloyd, Myc. Writ. **5**: 808. 1918.
Auricularia crassa Lloyd, Myc. Writ. **7**: 1275. 1924.

Fructification solitary, orbicular, rubbery-gelatinous when fresh, sessile to substipitate, up to 8 cm. broad; hymenial surface conspicuously merulioid to strongly porose-reticulate, this being the most striking macroscopic feature by which the species may be safely identified either in the field or in the herbarium.

Zona pilosa: Hairs extremely variable, 60–175 μ long, 5–6 μ in diameter, hyaline, without central strand, tips blunt or irregularly rounded, never in dense tufts.

Zona compacta: 20–30 μ wide, hyphae in dense aggregates, not individually distinguishable.

Zona subcompacta superioris: 40–50 μ wide, hyphae 2–3 μ in diameter, loosely arranged.

Zona intermedia: 400–500 μ wide, hyphae 2–2.5 μ in diameter,

arranged in a very loose reticulum having large interspaces, hyphae hyaline, thin-walled.

Zona subcompacta inferioris: 135–145 μ wide, hyphae 2–3 μ in diameter, becoming aggregated into a dense network.

Hymenium: 80–90 μ wide; basidia 40–45 $\times$ 4–5 μ; spores allantoid, with 2–3 prominent oil globules, 10–13 $\times$ 5–6 μ.

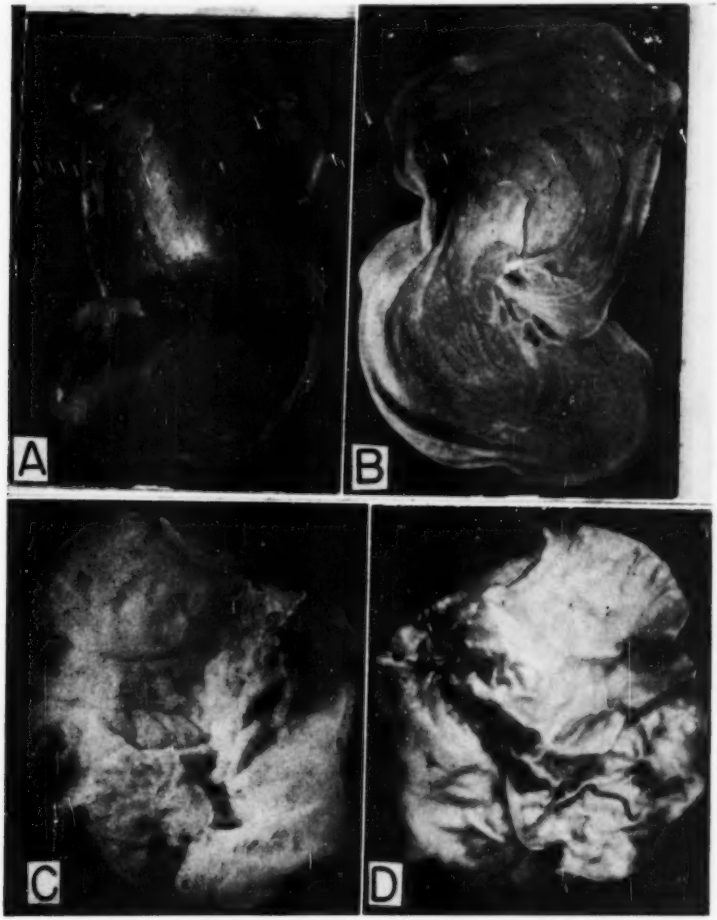

FIG. 4. A. *Auricularia auricula.* Inferior (hymenial) surface. B. Superior surface. Mo. Bot. Gard. *61172.* C. *Auricularia cornea.* Superior surface. D. Inferior surface. D. P. Rogers *1144,* Hawaii. $\times$ 1.

TYPE LOCALITY: Africa.

DISTRIBUTION: Mostly tropical America, Africa, Australia, South Pacific (FIG. 1).

ILLUSTRATIONS: N. Patouillard, Jour. de Bot. **1**: 226. *pl. 4, figs. 9–10.* 1887. A. R. Teixeira, Bragantia **5**: 181. *pl. IX.* 1945. E. A. Burt, Missouri Bot. Gard. Ann. **8**: 390. *pl. III, fig. 5.* 1921.

EXSICCATI: C. L. Smith, Central American Fungi *142.* C. Wright, Fungi Cubenses Wrightii *335.*

This species is common in the tropics and I have collected it on Barro Colorado Island. However, its range extends into subtropical areas (probably uncommon) and I have examined a specimen from southern Florida. This was collected by Rolf Singer in 1942 and is now on deposit in the Farlow Herbarium.

Auricularia delicata has been variously interpreted as an agaric, a polypore and a heterobasidiomycete. It was referred to the Auriculariaceae for the first time by Patouillard (**11**) in 1887. In a paper by Singer (**16**) the author states that "Patouillard should have buried the genus *Laschia* for good, once its identity with *Auricularia* was established." Although I share this opinion, it is not one which is universally held and it is the view of at least one prominent mycologist, Donk (**1**), that "the mycologist who wants to retain *Laschia* Fr. . . . defends a fair case."

A specimen from Ashanti, West Africa, collected by T. Hunter and sent to Lloyd (**5**) was named by him *A. Hunteri.* I have examined the type in the Lloyd collection and have determined it as *A. delicata.*

Lloyd (**5**) made the following comment on a specimen sent to him from India: "This I consider only a dark thick form of *A. delicata* . . . when soaked the peculiar hymenium of *A. delicata* is developed." Nevertheless he gave it a new name, *A. crassa.* The specimens which I examined from the Lloyd collection bearing this name were, beyond all reasonable doubt, *A. delicata.* I am therefore including *A. crassa* in the synonomy for this species.

4. AURICULARIA MESENTERICA Pers. Myc. Eur. **1**: 97. 1822. FIGS. 2, 8A, 11A, 13D, 15(23–27).

Auricularia lobata Sommerf. Mag. for Naturvidensk **7**: 296. 1826.
Exidia lobata (Sommerf.) Fries, Elench. **1**: 33. 1828.
Phlebia mesenterica (Pers.) Fries, Elench. **1**: 154. 1828.

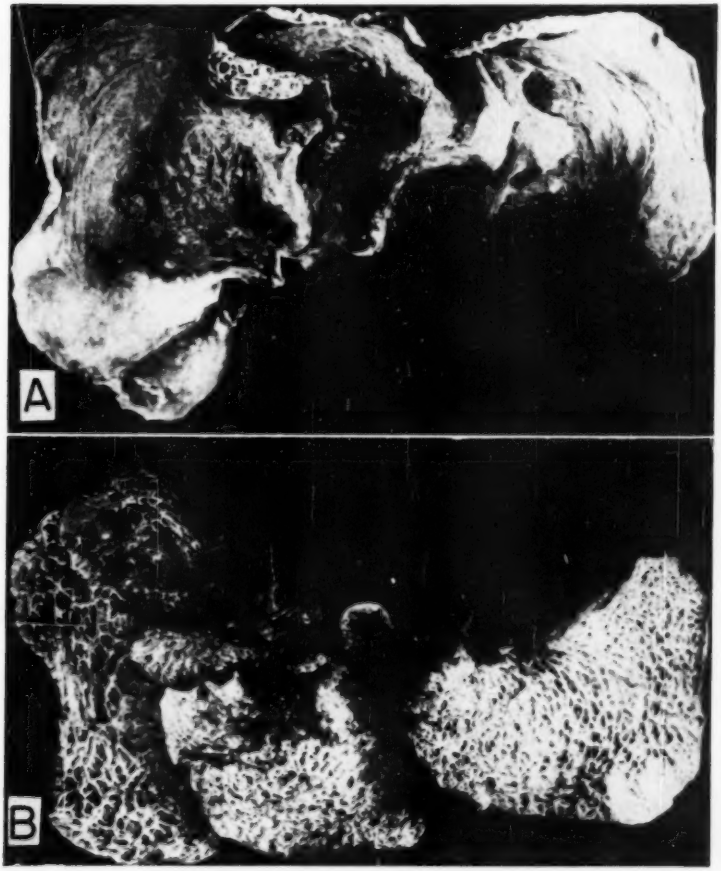

FIG. 5. A. *Auricularia delicata.* Superior surface. B. Inferior surface. G. W. Prescott *F-1,* Ecuador. × 1.

Auricularia mesenteriformis Link, Handb. **3**: 338. 1833.
Patila mesenterica (Pers.) Kuntze, Rev. Gen. **3**: 864. 1893.
Patila lobata (Sommerf.) Kuntze, Rev. Gen. **3**: 864. 1893.

Fructification at first resupinate, margins free, commonly lobed, 1.5–2 mm. or more in thickness; superior surface concentrically zonate.

Zona pilosa: Hairs about 500 μ or longer, 2–3 μ in diameter, hyaline to dark brown, without central strand, occurring in dense tufts.

Zona compacta: 80–90 μ wide, densely compacted, individual elements not distinguishable.

Zona subcompacta superioris: 130–150 μ wide, hyphae 2–3 μ in diameter, oriented mostly perpendicular to the surface.

Zona intermedia: 575–600 μ wide, hyphae 5–6 μ in diameter.

Zona subcompacta inferioris: 165–180 μ wide, hyphae 4–5 μ in diameter, oriented mostly perpendicular to the surface.

Hymenium: 115–125 μ wide; basidia 45–50 $\times$ 3–4 μ; basidiospores allantoid, 15–18 $\times$ 5–6 μ.

TYPE LOCALITY: Europe.

DISTRIBUTION: Europe; Tropical America from Florida to Argentina, Australia, Dutch East Indies (FIG. 2).

ILLUSTRATIONS: C. G. Lloyd, Myc. Writ. **5**: 783–785. *figs. 1175–1177.* 1918. A. R. Teixeira, Bragantia **5**: 183. *pl. XI.* 1945.

EXSICCATI: Rathay, Flora Exsiccata Austro-Hungarica *765* (as *Tremella mesenterica* Retzius). C. Wright, Fungi Cubenses Wrightiani *432.* C. Roumeguere, Fungi Selecti Exsiccati *7203.* Rabenhorst, Fungi Europaei *1215.* Rick, Fungi Austro-Americani *122.*

Persoon (**12**) in his original description of this species concisely recorded the most distinctive external feature of its superior surface as being composed of "zonis concentricis distinctus et hirsutus." Its resemblance to *A. ornata* is superficial.

5. AURICULARIA ORNATA Pers. in Gaudichaud, Bot. Freycinet, Voyage autor du Monde 177. 1827. FIGS. 3, 8B, 11B, 13E, 15(28–34).

Auricularia adnata Lyon in Rock, Hawaii Coll. Publ. Bull. **4**: 33. 1916.

Fructification with irregularly lobed margins, 1–1.5 mm. thick, pilose layer arranged in pattern of concentric zones alternating in series of wide and narrow bands; hymenial surface of mature speci-

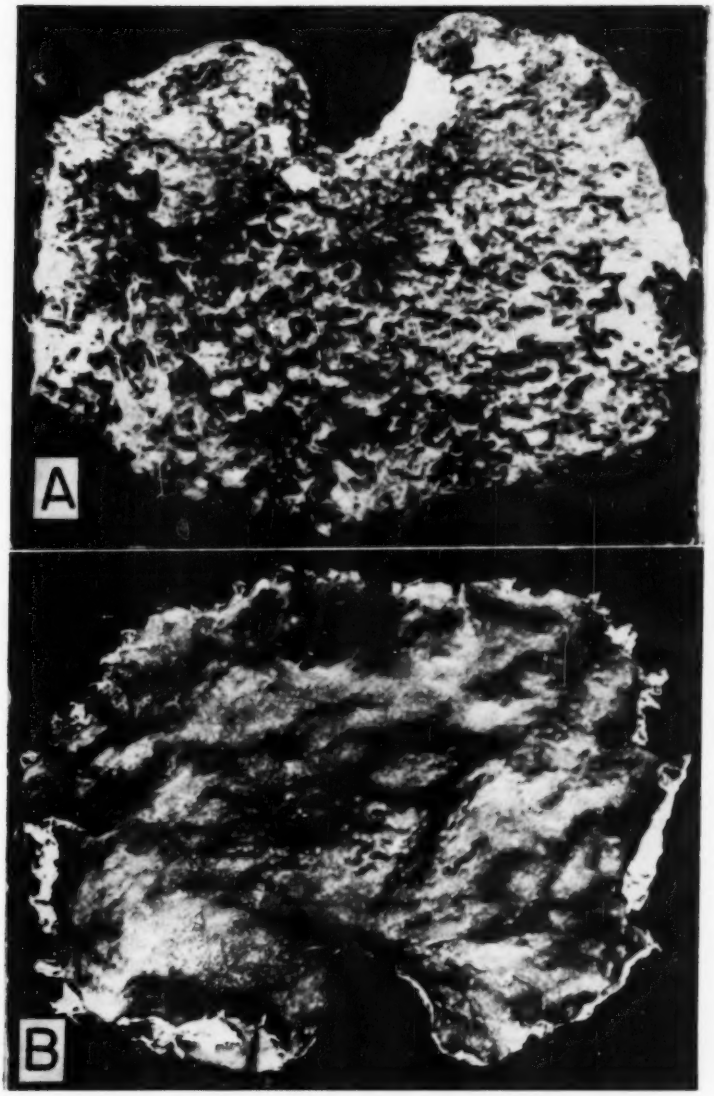

FIG. 6. A. *Auricularia Emini*. Superior surface. B. Inferior surface. McDonald, Nairobi, Africa. 1924. × 1.

mens conspicuously marked with more or less dichotomously branching, vein-like elevations.

Zona pilosa: Hairs about 450 μ long, 3–3.5 μ in diameter, hyaline to dark brown, tips pointed, arranged in dense tufts.

Zona compacta: 40–50 μ wide, very dense, individual hyphae not distinguishable.

Zona subcompacta superioris: 285–305 μ wide, hyphae 3–3.5 μ in diameter, orientation mostly perpendicular to the surface.

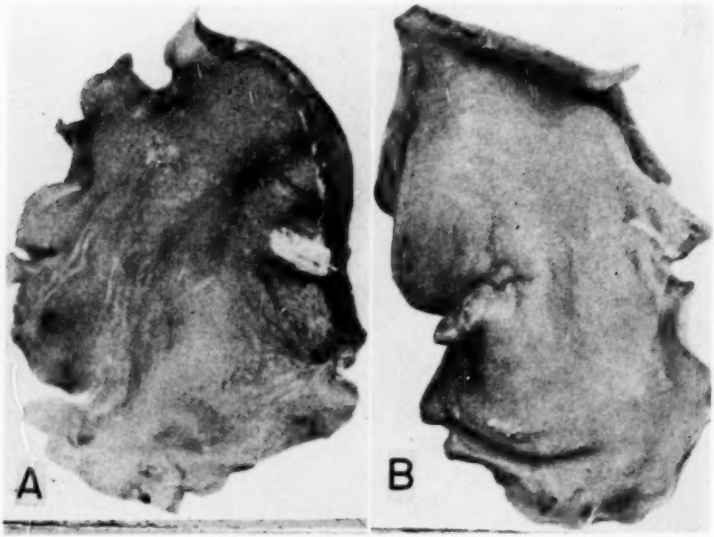

FIG. 7. A. *Auricularia fuscosuccinea.* Superior surface. B. Inferior surface. Type of *A. rosea* Burt. ×2.

Zona intermedia: 360–375 μ wide, hyphae 3–4 μ in diameter.

Zona subcompacta inferioris: 260–270 μ wide, hyphae 3–4 μ in diameter.

Hymenium: 60–75 μ wide; basidia clavate, 3-septate, 60–75 × 5–7 μ; spores 12–15 × 5–6 μ.

TYPE LOCALITY: Guam.

DISTRIBUTION: The Philippines and some Pacific Islands (FIG. 3).

ILLUSTRATIONS: C. H. Persoon, in Gaudichaud. Bot. Freycinet, Voyage autor du Monde 177. *pl. 2, fig. 4.* 1827.

Rogers (**14**) has collected this species in the Marshall Islands and believes that it is identical with *A. adnata* of Lyon. Persoon (**12**) in his original description of the species states that the superior surface is somewhat similar to *A. mesenterica*. Rogers considers that "the two species are undoubtedly closely related" but "amply distinct." I have been able to confirm these observations to my own satisfaction from evidence of internal structure and find that the species are easily separated.

6. AURICULARIA PELTATA Lloyd Myc. Writ. **7**: 1117. 1922. FIGS. 1, 9B, 12C, 14A, 15(35–40).

Fructification disciform, resupinate, with fimbriate but free margins, becoming confluent.

Zona pilosa: Hairs 70–80 μ long, 3–3.5 μ in diameter, hyaline to light brown, central strand prominent, tips rounded.

Zona compacta: 50–60 μ wide, densely compacted, individual hyphae not distinguishable.

Zona subcompacta superioris: 290–310 μ wide, hyphae 3–4 μ in diameter, orientation mostly perpendicular to the surface.

Zona intermedia: 345–360 μ wide, hyphae 4–5 μ in diameter.

Zona subcompacta inferioris: 315–335 μ wide, hyphae 3–4 μ in diameter.

Hymenium: about 150 μ wide, with masses of amorphous crystaline material scattered throughout and also extending into the zona intermedia; basidia 35–45 × 3.5–4 μ, becoming transversely 3-septate; basidiospores allantoid, 11–13 × 5–5.5 μ.

TYPE LOCALITY: Mt. Maquiling, Luzon, Philippine Islands.

DISTRIBUTION: Africa, China, India, Panama, Philippines (FIG. 1).

EXSICCATI: C. Torrend, Mycotheca Africana *98*.

Through the courtesy of Mr. J. A. Stevenson I have been able to examine material from the type collection. The specimen upon which the species was based was collected by A. Serrano on dead wood of *Cordia myxa* on October 3, 1920. This was sent by O. A. Reinking to Lloyd who, though he found neither basidia nor spores, correctly identified it as an *Auricularia*. In examining sections of the type, I found good basidia but no spores. However, in a specimen from Uganda, I found spores of the characteristic allantoid shape.

7. AURICULARIA POLYTRICHA (Mont.) Sacc. Atti R. Instit. Veneto Vi **3**: *722.* 1885. FIGS. 3, 9A, 12A, 13B, 15(41–47).
Exidia polytricha Mont. in Belanger, Voy. aux Indes 154. 1834.

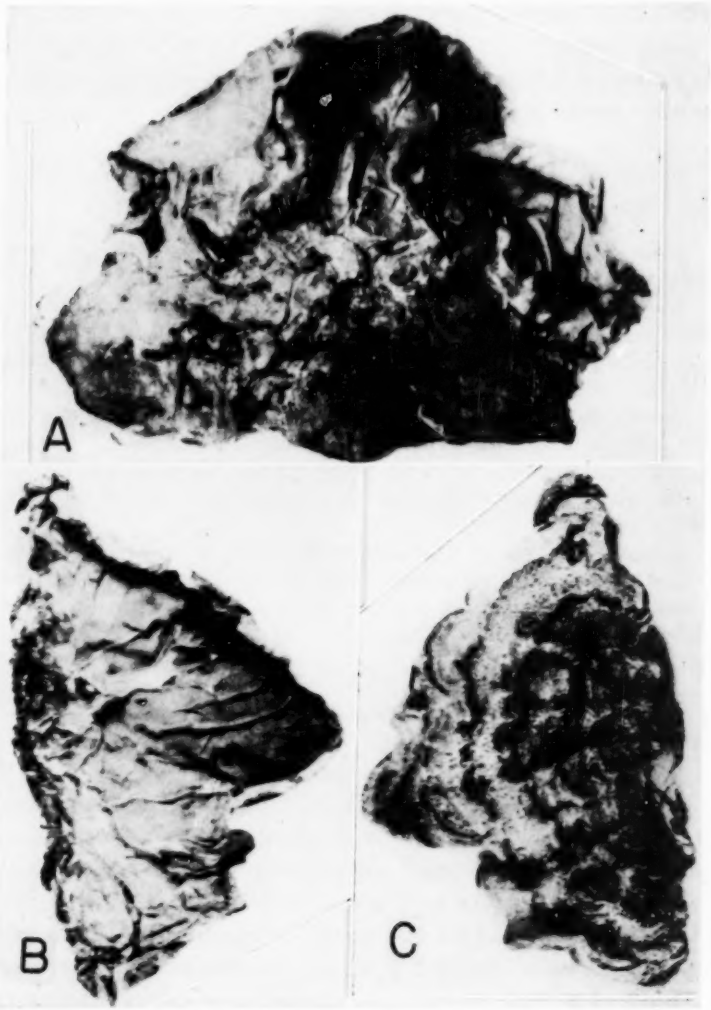

FIG. 8. A. *Auricularia mesenterica.* Superior surface. G. Fuhrer ex Herb. Neuhoff. B. *Auricularia ornata.* Inferior surface. C. Superior surface. Topotype. ×1.5. M. M. Ross *9* & K. L. Machler. Guam.

Exidia purpurescens Jungh. Praem. 25. 1838.

Exidia hispidula Berk. Ann. Nat. Hist. II, **3**: 396. 1839.

Exidia porphyrea Lév. Champ. Exot. III, **2**: 218. 1844.

Hirneola nigra Fries, Fung. Nat. 27. 1848.

Hirneola porphyrea (Lév.) Fries, Fung. Nat. 27. 1848.

Hirneola polytricha (Mont.) Fries, K. Vet.-Akad. Handl. **1848**: 146. 1849.

Hirneola hispidula Berk. Jour. Linn. Soc. **14**: 352. 1874.

Auricula nigra (Fries) Kuntze, Rev. Gen. pl. **2**: 844. 1891.

Auricula polytricha (Mont.) Kuntze, Rev. Gen. pl. **2**: 844. 1891.

Auricula nigra (Sw.) Earle, Bull. Torrey Bot. Club **26**: 633. 1899.

Auricularia hispidula (Berk.) Farlow, Bibl. Index **1**: 307. 1905.

Auricularia nigrescens (Sw.) Farlow, Bibl. Index **1**: 308. 1905.

Auricularia porphyrea (Lév.) Teixeira, Bragantia **5**: 163. 1945.

Fructification frequently having a strongly convex dorsal surface, densely pilose, largest specimens 5–6 cm. broad, 1–1.5 mm. thick.

Zona pilosa: Hairs about 450 μ long, hyaline, 5–6 μ in diameter, forming dense tufts, with a prominent central strand, tips pointed but frequently broken, appearing truncate when viewed microscopically.

Zona compacta: 20–25 μ wide, densely compacted, individual hyphae not distinguishable.

Zona subcompacta superioris: 75–85 μ wide, hyphae 2–3 μ in diameter, oriented mostly perpendicular with the surface.

Zona laxa superioris: 250–260 μ wide, hyphae 3–4 μ in diameter.

Medulla: About 250 μ wide, hyphae 3–5 μ in diameter, oriented mostly parallel with the surface.

Zona laxa inferioris: 250–260 μ wide, hyphae 3–4 μ in diameter.

Zona subcompacta inferioris: 90–100 μ wide, hyphae 2–3 μ in diameter.

Hymenium: 80–90 μ wide; basidia cylindrical, 50–60 $\times$ 4–5 μ; spores 12–15 $\times$ 5–6 μ.

TYPE LOCALITY: Jamaica.

DISTRIBUTION: Tropical America from Florida to Argentina, Africa, Australia, Pacific Islands (FIG. 3).

EXSICCATI: H. C. Funck, Cryptogamische Gewaschse des Fichtelgeberges (as *Tremella Auricula Judae* Pers.). R. Maire, Myco-

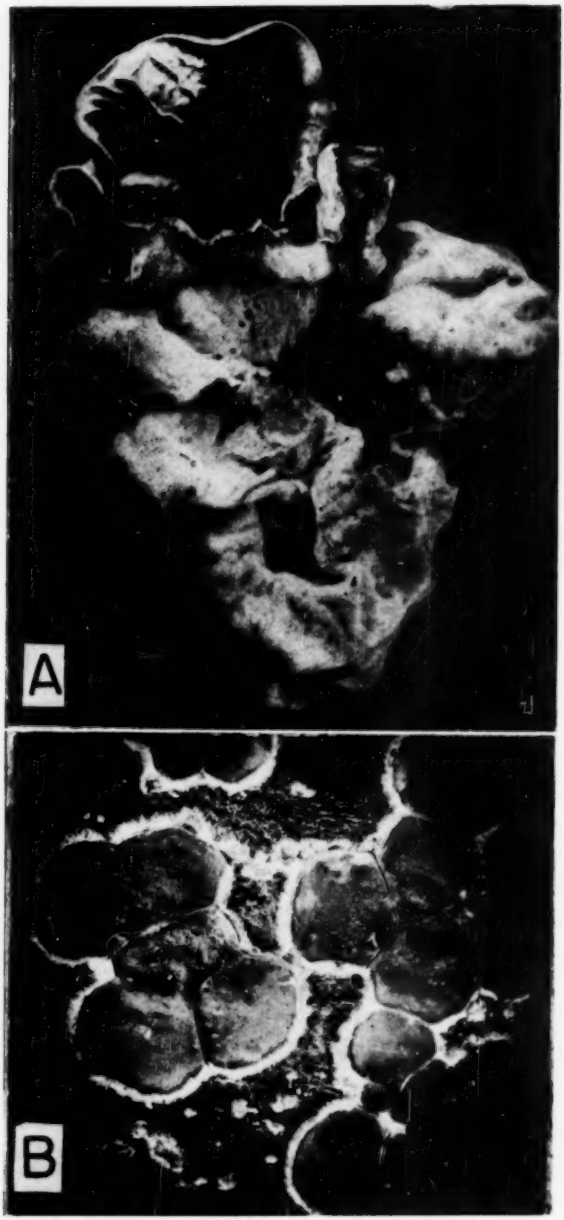

FIG. 9. A. *Auricularia polytricha,* showing mostly superior surface with part of inferior surface at top of figure. × 1. B. *Auricularia peltata.* Type. U. S. Nat. Herb. *33289.* × 1.5.

theca Boreali Africana *67* (as *Auricularia auricula-Judae* (Fr.) Quél.).

This species is of wide occurrence throughout the tropical and subtropical regions of the world, where it is as commonly found as is *A. auricula* in temperate areas. A. P. Viegas (**18**), for example, reports that it is quite common in São Paulo, Brazil. Lloyd (**4**) considered *A. polytricha* to be a tropical form of *A. auricula*, but his opinion was based upon superficial characters of the fruiting body, not upon internal structure. Of the species I have examined from North America, some specimens from Southern New Mexico represent its most Northern range. I have seen it in the living condition and have collected it on Barro Colorado Island. Its superior surface is usually densely pilose but very variable in color so that at times it may be confused with *A. tenuis*, which, however, has much shorter hairs and is entirely distinct in section. A number of names have been applied to this fungus, Montagne's epithet being the earliest valid one which has come to my attention. Farlow (**2**) states that Swartz gave it the name *Peziza nigricans* in 1788 and that in 1806 he changed the name "for some unknown reason" to *P. nigrescens*. Fries (**3**) in Syst. Myc. **2**: 81. 1823, adopted the latter name. The fact that Swartz noted the habit as being "ad terram" makes it doubtful that this is the valid name for the species under consideration. Since Swartz's original collection is not accessible, Montagne's combination, *A. polytricha*, should be considered the valid one.

The date of Belanger's voyage is given by Montagne in Syll. Crypt. XVIII. 1856 as 1834, but Pritzel (**13**) records it as 1836. The earlier date is further confirmed in a posthumous publication of Montagne dated 1865.

Ribeiro Teixeira (**17**), in Bragantia, established a new combination, *A. porphyrea*. Under the heading of "observations," in describing the species he states that "esta especie e muito semelhante a *A. polytricha*, da qual e separada pelo tomento ruivo muito caracteristico. Nas demais particularidades, sao bem semelhantes." In view of the fact that the new species is established on the basis of the difference in a single character which is subject to considerable variation and that in every other way it is similar to *A. polytricha*, it seems improbable to me that this is really a new entity. Photo-

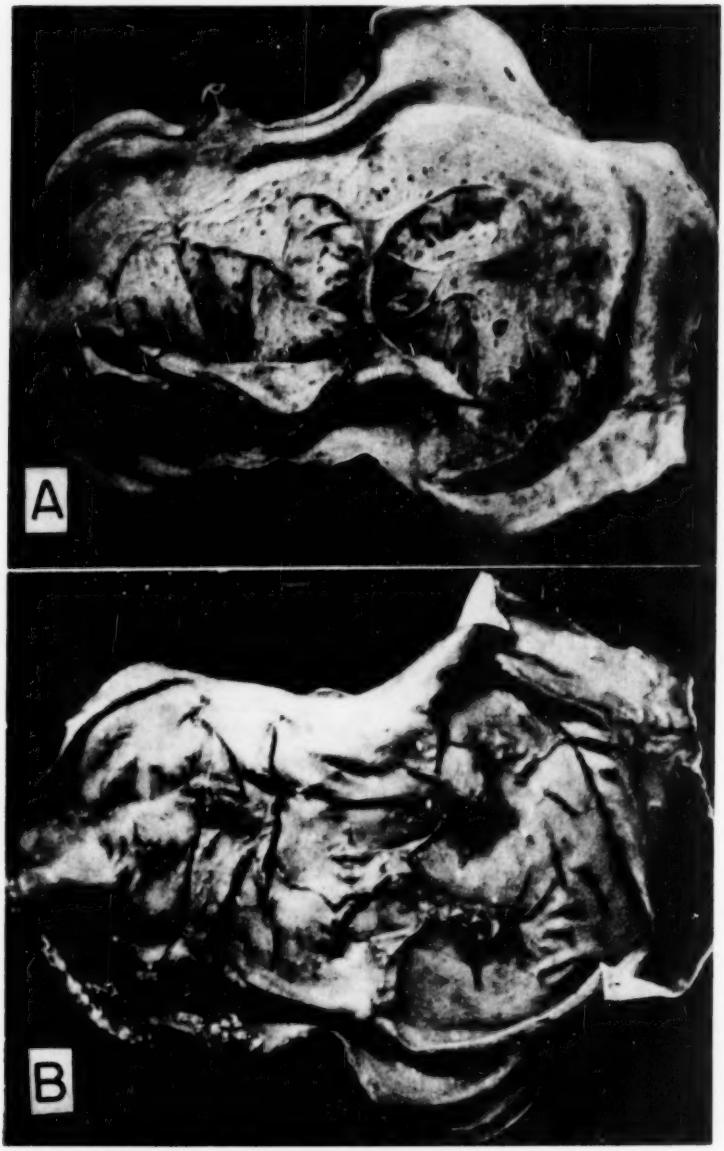

FIG. 10. A. *Auricularia tenuis*. Superior surface. B. Inferior surface. British Museum *166*. × 1.5.

graphs of several fruiting bodies conform very well with what I have seen of *A. polytricha*. For these reasons I am including *A. porphyrea* (Lév.) Teixeira with the synonymy of the species.

8. AURICULARIA FUSCOSUCCINEA (Mont.) Farlow, Bibl. Index **1**: 307. 1905. FIGS. 2, 7A, B, 12E, 13C, 15(48–55).

Exidia fuscosuccinea Mont. Pl. Cell. Cuba 346. 1841.
Hirneola nigra var. *fuscosuccinea* Fries, Fung. Nat. 27. 1848.
Hirneola fuscosuccinea Mont. Syll. Crypt. 181. 1856.
Auricularia brasiliensis Lloyd, Myc. Writ. **5**: 785. 1918.
Auricularia rosea Burt, Ann. Mo. Bot. Gard. **8**: 391. 1921.
Auricularia stellata Lloyd, Myc. Writ. **7**: 1151. 1921.
Auricularia flava Lloyd, Myc. Writ. **7**: 1153. 1922.
Auricularia mollis Lloyd, Myc. Writ. **7**: 1198. 1923.

Fructifications mostly pileate, solitary to gregarious, thin, translucent when dry, largest specimens about 12 cm. broad, 0.5–0.8 mm. thick.

Zona pilosa: Hairs 60–80 μ long, 4–5 μ wide, hyaline, without central strand, rounded at tips.

Zona compacta: 25–35 μ wide, densely compacted, individual hyphae not distinguishable.

Zona subcompacta superioris: 10–15 μ wide, hyphae 3–4 μ in diameter.

Zona laxa superioris: 140–150 μ wide, hyphae 3–5 μ in diameter.

Medulla: 35–50 μ wide, composed of a single dense band of hyphae occasionally slightly abhymenial in position, hyphae 3–4 μ in diameter, oriented mostly parallel with the surface.

Zona laxa inferioris: 150–160 μ wide, hyphae 3–4 μ in diameter.

Zona subcompacta inferioris: 60–70 μ wide, hyphae 3–4 μ in diameter.

Hymenium: 70–80 μ wide; basidia 50–60 $\times$ 4–5 μ, cylindrical; basidiospores 12–14 $\times$ 4–5 μ, allantoid.

TYPE LOCALITY: Cuba.

DISTRIBUTION: South temperate and tropical America from Tennessee to Argentina; Australia, Philippines, Dutch Guiana (FIG. 2).

ILLUSTRATIONS: E. A. Burt, Ann. Mo. Bot. Gard. **8**: 396. *pl. III, figs. 6–8.* 1921.

In the fresh state this species is not likely to be confused with any other. Although subject to drastic changes in color upon

drying, the living specimens are distinctly rosy to vinaceous. I have collected it on Barro Colorado Island and have examined a large number of specimens, including the type which I was permitted to examine through the courtesy of Dr. C. W. Dodge of the Missouri Botanical Garden. Its northernmost range in North America is probably Tennessee; two collections from that state, identical in every way with tropical material I have seen, are on deposit in the mycological herbarium of the State University of Iowa.

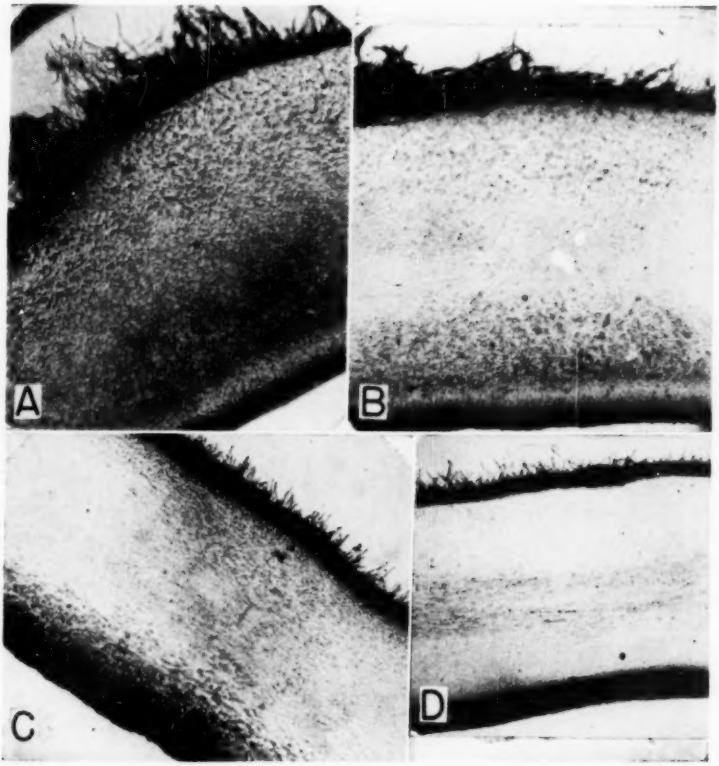

FIG. 11. A. *Auricularia mesenterica.* G. Fuhrer ex Herb. Neuhoff. B. *Auricularia ornata.* Topotype. M. M. Ross 9 & K. L. Machler. Guam. C. *Auricularia auricula.* G. W. Martin *708,* Iowa City. D. *Auricularia tenuis.* C. Garces *1654,* Colombia. Approximately × 75.

Lloyd (**7**) shows photographs of an *Auricularia* collected by C. Domingo in North Borneo, to which he has assigned the specific epithet *stellata*. The feature which led Lloyd to erect a new species was the presence of "six (or seven) symmetrically thickened, tapering, bifid veins" radiating from the central attachment, giving to the short stipe a stellate appearance. The remainder of the description, as well as the photographs, conforms very well with what we might normally expect of *A. fuscosuccinea*. The fact that the region of attachment to the substrate had a stellate appearance does not, in my opinion, warrant establishing a new species and should be considered a fortuitous circumstance susceptible of considerable variation.

I have seen a number of specimens from the Lloyd collection identified by Lloyd as a new species, *A. brasiliensis*. He called it a "rare, smooth, tropical form of the 'Jew's ear.'" Since, upon examination, all of these proved to be *A. fuscosuccinea*, I am including *A. brasiliensis* as a synonym of *A. fuscosuccinea*. A specimen sent to Lloyd by P. van der Bijl from South Africa is described by Lloyd (**4**) as "resupinate, scanty and unsatisfactory." Nevertheless he gave it a new name, *A. flava*. The color of this species is described as "near old gold" when wet, which is suggestive of *A. fuscosuccinea*. I have examined the type and determined it as *A. fuscosuccinea*.

Another species erected by Lloyd was named *A. mollis*. Lloyd (**6**) describes it as "glabrous to the eye . . . but under the lens are scattered, glandular hairs." I have identified it as *A. fuscosuccinea*.

9. AURICULARIA TENUIS (Lév.) Farlow, Bibl. Index **1**: 309. 1905. FIGS. 3, 10A, B, 11D, 13D, 15(56–62).

Exidia tenuis Lév. Ann. Sci. Nat. III, **2**: 219. 1844.

Hirneola tenuis Fries, Nov. Acta Roy. Soc. Sci. Upsala III, **1**: 118. 1851.

Hirneola tenuis (Lév.) Fries, K. Vet.-Akad. Handl. **1848**: 147. 1849.

Auricula tenuis (Lév.) O. Kuntze, Rev. Gen. pl. **2**: 844. 1891.

Fructification mostly solitary, 0.8–1.0 mm. thick, tough-gelatinous when wet, up to 8–10 cm. in breadth.

Zona pilosa: Hairs 85–100 μ long, 5–6 μ in diameter, hyaline to light brown, central strand prominent, tips rounded.

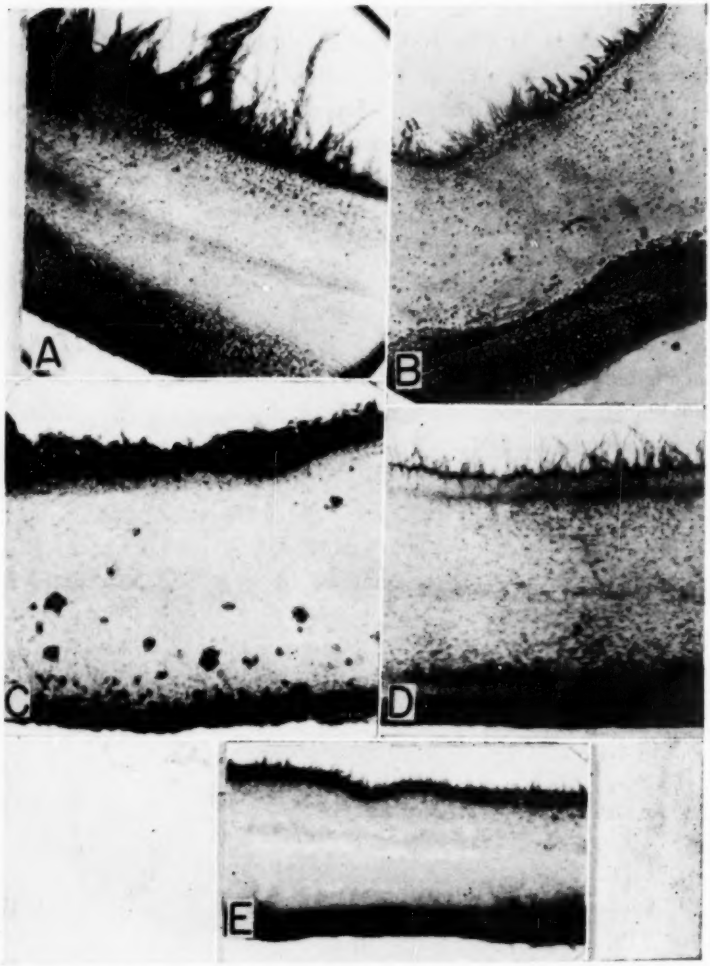

FIG. 12. A. *Auricularia polytricha.* B. Lowy *1015,* Barro Colorado. B. *Auricularia delicata.* G. W. Martin *4000,* Barro Colorado. C. *Auricularia peltata.* R. A. Dummer *2361,* Uganda. D. *Auricularia cornea.* D. P. Rogers *1354,* Hawaii. E. *Auricularia fuscosuccinea.* Mo. Bot. Gard. Costa Rica. Approximately × 75.

Zona compacta: 40–50 μ wide, densely compacted, individual hyphae not distinguishable.

Zona subcompacta superioris: 20–30 μ wide, hyphae 4–5 μ in diameter, oriented mostly parallel with the surface.

Zona laxa superioris: 195–210 μ wide, hyphae 5–6 μ in diameter.

Medulla: 190–210 μ wide, composed of two dense strands each about 75 μ wide, separated from each other by a zone of loosely arranged hyphae 30–40 μ wide.

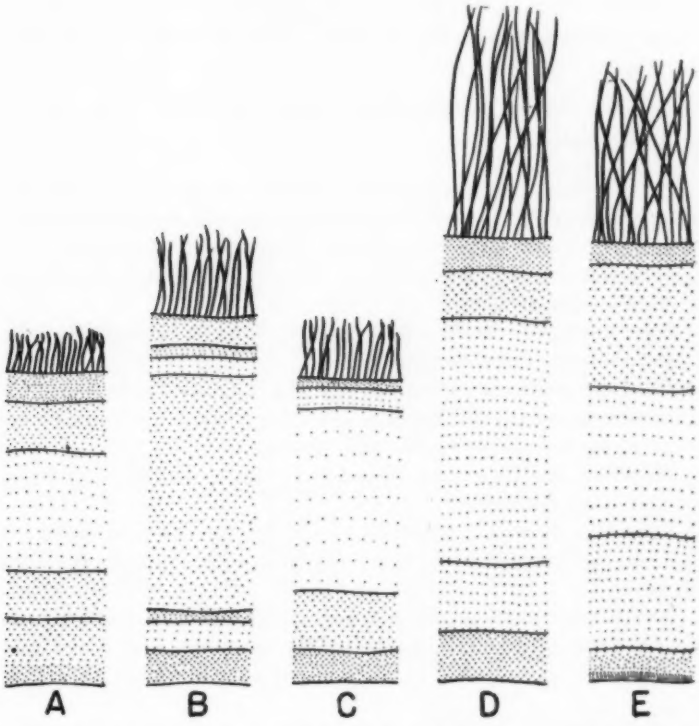

FIG. 13. A. *Auricularia auricula.* B. *Auricularia cornea.* C. *Auricularia delicata.* D. *Auricularia mesenterica.* E. *Auricularia ornata.* Figures approximately × 95.

Zona laxa inferioris: 170–185 μ wide, hyphae 3–4 μ in diameter.

Zona subcompacta inferioris: 20–30 μ wide, hyphae 4–6 μ in diameter.

Hymenium: 80–90 μ wide; basidia 50–60 × 4–6 μ; basidiospores 12–15 × 5–6 μ.

TYPE LOCALITY: Borneo.

DISTRIBUTION: Mexico, South America, Hawaii, Philippines, Borneo (FIG. 3).

In gross morphology, *A. tenuis* may be confused with *A. polytricha*, but they are quite distinct in section. The relative shortness of the hairs of *A. tenuis* also serves to distinguish them.

10. AURICULARIA EMINI P. Henn. Fung. Afr. **2**: 19. *tab. 1, fig. 2.* 1893. FIGS. 2, 6A, B.

Auricularia squamosa Pat. & Hariot, Bull. Soc. Myc. Fr. **9**: 210. 1893.

Hirneola floccosa Wakef. Niger. Fungi. Kew Bull. Misc. Inf. **3**: 108. 1917.

Fructification tough-coriaceous, solitary, sessile; 10–12 cm. or more broad, context 0.6–0.9 mm. thick; superior surface conspicuously matted with long brown hairs, squamous in appearance.

Zona pilosa: Hairs 3–5 cm. long, 3–5 μ in diameter, light brown, without central strand.

Zona compacta: 60–70 μ wide, hyphae in dense aggregates, individual elements not distinguishable.

Zona subcompacta superioris: 40–50 μ wide, 2–3 μ in diameter.

Zona laxa superioris: 150–160 μ wide, hyphae 2–4 μ in diameter, oriented mostly perpendicular with the surface.

Medulla: 90–100 μ wide, hyphae 2–5 μ in diameter, oriented parallel with the surface.

Zona laxa inferioris: 140–150 μ wide, hyphae 2–4 μ in diameter.

Zona subcompacta inferioris: 40–50 μ wide, hyphae 2–4 μ in diameter.

Hymenium: 60–70 μ wide, compact; basidia clavate to cylindrical, 45–55 $\times$ 4–6 μ, becoming 3-septate; basidiospores allantoid, 12–14 $\times$ 4–5 μ.

TYPE LOCALITY: Africa.

DISTRIBUTION: Africa (FIG. 2).

ILLUSTRATIONS: C. G. Lloyd, Myc. Writ. **4**: 1229. *pl. 258, fig. 2562.* 1923 (as *A. squamosa*).

The gross morphology of this species, known only from Africa, makes it the most distinctive of the auriculariaes. It is less gelatinous than the others when soaked up; this feature, together with the exceedingly long hairs, makes its identification simple. All the

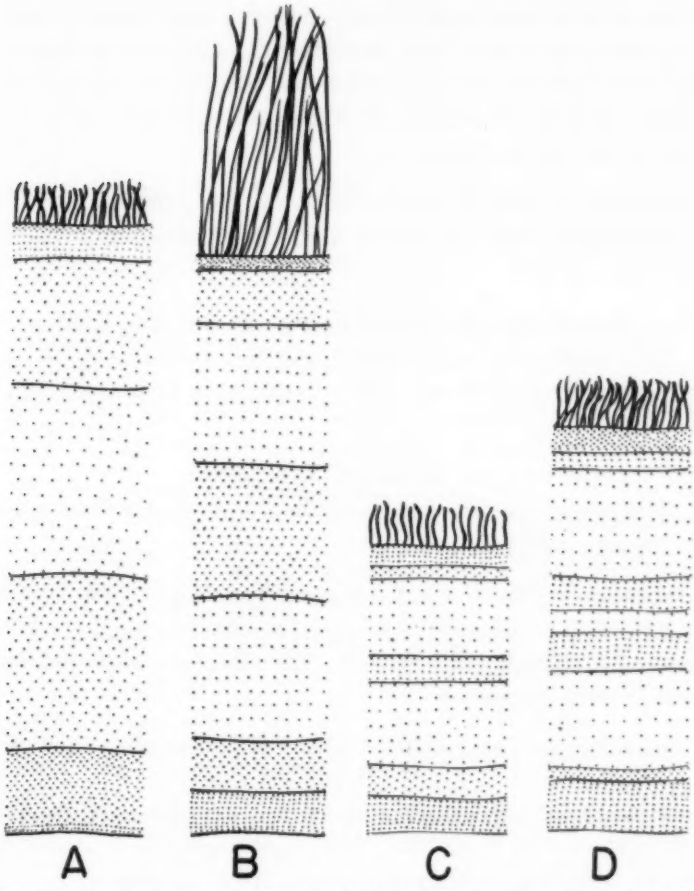

FIG. 14. A. *Auricularia peltata.* B. *Auricularia polytricha.* C. *Auricularia fuscosuccinea.* D. *Auricularia tenuis.* *Figures approximately* × 95.

specimens which I have seen are part of the Lloyd mycological collection, now deposited in the U. S. National Herbarium.

SPECIES INQUIRENDAE

Auricularia albicans (Berk.) Lloyd, Myc. Writ. **7**: 1363. 1925.

I have not been able to find authentic material to examine. Lloyd states that "surely it is only a pale form of the common 'Jew's ear.'"

Auricularia blepharistoma (B. & C.) Farlow, Bibl. Index. 1905.

Berkeley and Curtis, using the name *Hirneola,* describe this as "pileo conchiformi, velutino, luteo-fusco, margine setis conspicuis ciliato; hymenio plicate, atro." I have not found any specimens bearing this specific epithet.

Auricularia Bresadolae Schulz. Hedw. **24**: 148. 1885.

The original description of this species is suggestive of *A. fusco-succinea.*

Auricularia buccina Pat. Bull. Soc. Myc. Fr. **14**: 154. 1898.

This species was based upon a specimen from Tahiti but its original description is not sufficiently complete to permit identification.

Auricularia Cati Fries, Linnaea **5**: 526. 1830.

This species is reported as coming from Australia but it is known to me only from the literature.

Auricularia coffeicolor (Berk.) Farlow, Bibl. Index **1**: 306. 1905.

According to Saccardo (Syll. Fung. **6**: 770) this species is from Australia. Farlow (Bibl. Index **1**: 306) lists it as a ***nomen novum*** and gives no diagnosis.

Auricularia dacryomycetospora Speg. Fung. Guar. Pug. I. no. 90. 1886.

I have seen only a single specimen bearing this specific epithet (Lloyd collection *No. 38790*). This was determined by Professor G. W. Martin as *Dacryopinax elegans* (B. & C.) Martin.

Auricularia fucoidea Pers. in Guad. Bot. 177. 1827.

I have not seen any specimens of this Brazilian species but according to Persoon, "Il différe aussi des autres espèces, en ce qu'il n'a aucune villosité en dessous."

Auricularia indica Massee, Kew Bull. 75. 1914.

The description of this species given by Massee is suggestive of *A. delicata.* It was reported from Singapore.

Auricularia intestinalis Lloyd, Myc. Writ. **5**: 185. 1918.

According to Lloyd, "this rare species of which only two collections are known passes now in our literature as *Favolus* or *Laschia*." The photo published by Lloyd is suggestive of *A. delicata*.

Auricularia lenta Fries, Nov. Symb. Myc. 113. 1851.

I have not seen any specimens bearing this specific epithet. It is reported as coming from Brazil.

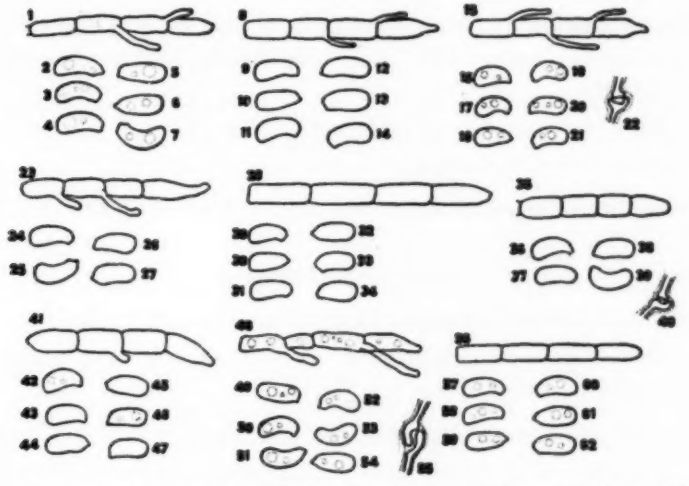

FIG. 15. 1–7. *Auricularia auricula*. G. W. Martin *708*. 1. Basidium with epibasidia. 2–7. Spores. 8–14. *Auricularia cornea*. D. P. Rogers *1345*. 8. Basidium with epibasidia. 9–14. Spores. 15–22. *Auricularia delicata*. G. W. Prescott *F-1*. 15. Basidium with epibasidia. 16–21. Spores. 22. Clamp-connection. 23–27. *Auricularia mesenterica*. G. Fuhrer ex Herb. Neuhoff. 24–27. Spores. J. Rick, Brazil. No number. 28–34. *Auricularia ornata*. Topotype. M. M. Ross 9 & K. L. Machler. 28. Basidium. 29–34. Spores. 35–40. *Auricularia peltata*. R. A. Dummer *2361*. 35. Basidium. 36–39. Spores. 40. Clamp-connection. 41–47. *Auricularia polytricha*. British Museum *1242*. 41. Basidium. 42–47. Spores. 48–55. *Auricularia fusco-succinea*. Mo. Bot. Gard. Type of *A. rosea*. 48. Basidium with epibasidia. 49–54. Spores. 55. Clamp-connection. 56–62. *Auricularia tenuis*. British Museum *166*. 56. Basidium. 57–62. Spores. All figures drawn with camera lucida and reproduced to approximately × 1000.

Auricularia minuta Berk. Lond. Jour. Bot. **4**: 59. 1845.

Saccardo (Syll. Fung. **6**: 764) records this species as coming from Australia and Tasmania. Its description is not suggestive of an *Auricularia*.

Auricularia pusio Berk. in Linn. Jour. **17**: 386. 1878.

In Syll. Fung. **23**: 557 this species is listed as a synonym of *A. mesenterica pusio* (Dicks.) Fries.

Auricularia sordescens Cesati, Myc. Born. in Atti. Acad. Sci. Nap. **8** (3): 10. 1879.

Auricularia Syringae Fuckel, Symb. Myc. App. II, 9. 1870.

Auricularia velutina (Lév.) Pat. Jour. de Bot. **1** (15): 225–232. 1887.

From the description and illustrations of Patouillard, this species is suggestive of *A. delicata*.

Auricularia Vespertilio Fries, Nov. Act. R. Soc. Upsal. III, **1**: 112. 1851.

SPECIES EXCLUDENDAE

Auricularia amethystea Bull. Hist. Champ. Fr. 1809.

Bulliard includes this species as one of the varieties of *A. reflexa*, which in the modern sense is a *Phlebia*.

Auricularia aurantiaca Sowerby, Ill. Eng. Fungi **3**. 1803.

The illustration of this fungus is totally unlike any known *Auricularia*. It is suggestive of a polypore rather than of a heterobasidiomycete.

Auricularia byssoidea (D.C.) Mérat, Fl. Envir. Paris. 1821.

Mérat reports this species as occurring "sur les mousses," not a likely substrate for an *Auricularia*. To my knowledge, none of the species of *Auricularia* are parasitic.

Auricularia calcea (Pers.) Mérat, Fl. Envir. Paris. 1821.

Persoon, describing this species as a *Thelephora*, says that it is "sicca, glabra, dura, subrimosa; detrita fuscens, papillis manifestis." Mérat adds, "parfaitment glabre, lègerment fendillee."

Auricularia caerulea (D.C.) Mérat, Fl. Envir. Paris ed. 2. 1821.

This is a resupinate, non-auriculariaceous species described by De Candolle as a *Thelephora*.

Auricularia cantherella (Schw.) Fries, Syst. Orb. Veg. 83. 1825.

Schweinitz (**15**) (no. *1000*) describes this species as having "pileo infundibuliformi, hymenii papillis raris." He includes it under *Thelephora*.

Auricularia cariophyllea (Bull.) Mérat, Fl. Envir. Paris ed. 2. 1821.

Bulliard's figures are more suggestive of a thelephoraceous fungus than of an auriculariaceous one.

Auricularia cinerea Sowerby, Ill. Eng. Fungi **3**. 1803.

Sowerby says that this fungus "spreads very much, and has mostly a brownish margin. The middle is generally full of irregular protuberances." His illustration resembles a *Hymenochaete*.

Auricularia corticalis (Bull.) Mérat, Fl. Envir. Paris ed. 2. 1821.

The species illustrated by Bulliard appears corticioid.

Auricularia corrugata Sowerby, Ill. Eng. Fungi. 1800.

Sowerby reports that the underside is light brown, "becoming darker . . . and more corrugated when it grows older." It may be a *Stereum*.

Auricularia discensa Lloyd, Myc. Writ. **6**: 902. 1919.

Lloyd describes this species, from Brazil, as "cerebriform, gelatinous and simulating a *Tremella* rather than *Auricularia*."

Auricularia elegans Sowerby, Ill. Eng. Fungi. 1810.

As Sowerby states, this is "a very elegant specimen" but it looks very much like an agaric.

Auricularia euphorbaecola Pat. Bull. Soc. Myc. Fr. **9**: 137. 1893.

Patouillard states that this species has a "chapeau couvert de crêtes fines et scillantes."

Auricularia ferruginea (Bull.) Mérat, Fl. Envir. Paris. 1821.

Bulliard characterizes the inferior surface of this fungus as having "papilles agglutines les unes aux autres."

Auricularia frustulosa (Pers.) Mérat, Fl. Envir. Paris ed. 2. 1821.

Persoon includes this species under *Thelephora*. His description is suggestive of a *Stereum*.

Auricularia grisea (Schw.) Fries, Syst. Orb. Veg. 82. 1825.

Schweinitz notes that this is a "rara et distincta species." It is described as a *Thelephora*.

Auricularia muscigena (Pers.) Mérat, Fl. Envir. Paris ed 2. 1821.

Persoon describes this species as a *Thelephora* and there is no indication that it is an *Auricularia* in the modern sense.

Auricularia pannosa Fries, Syst. Orb. Veg. 83. 1825.

Fries comments that this species grows "ad terram," an unlikely place for an *Auricularia*.

Auricularia papyrina (Bull.) Mérat, Fl. Envir. Paris ed. 2. 1821.

"Poreuse inférieurment comme un bolet" is Mérat's characterization of this fungus.

Auricularia persistens Sowerby, Ill. Eng. Fungi. 1803.

Sowerby says that this species "differs very little if at all from *A. reflexa*," which is a *Phlebia*.

Auricularia phylacteris (Bull.) Mérat, Fl. Envir. Paris ed. 2. 1821.

This is another species reported as growing on the ground.

Auricularia Persoonii (D.C.) Mérat, Fl. Envir. Paris ed. 2. 1821.

The illustration to which Mérat refers is one of Bulliard's (*plate 378*), suggestive of a *Hymenochaete*.

Auricularia polygonia (Pers.) Mérat, Fl. Envir. Paris ed. 2. 1821.

Mérat's description indicates that this is a resupinate species from Europe. *A. peltata*, the only resupinate species of *Auricularia*, is not known from Europe.

Auricularia protracta (Lév.) Pat. & Lagerh. Bull. Soc. Myc. Fr. **9**: 137. 1893.

Léveille described this as a new species of *Exidia*. He states: "ces chapeaux . . . se prolongent en cort pedicule . . . 6 a 8 cm. de haut." This does suggest an *Auricularia*.

Auricularia perverulenta Sowerby, Ill. Eng. Fungi **2**: 1799.

Sowerby says that this species "protrudes umbillically in concentric circles emitting a snuff-colored powder." Fries refers the species to *Merulius perverulentus*.

Auricularia reflexa (Berk.) Bres. Ann. Myc. **9**: 273. 1911.

Specimens which I have examined bearing this name have all been referable to *Phlebia*.

Auricularia regularis (Schw.) Fries, Syst. Orb. Veg. 83. 1825.

Schweinitz notes that this species has a "hymenium subpapillosum" and is described as a *Thelephora*.

Auricularia Schulzeri Quél. et Bres. Hedw. **24**: 148. 1885.

The original description of this species is not suggestive of an *Auricularia*.

Auricularia scutellaeformis Lloyd, Myc. Writ. **7**: 1275. 1924.

"Applanate, flat, thin black bodies" is Lloyd's description of this species. Farlow referred it to *Exidia*.

Auricularia strigoso-zonata (Schw.) Bres. Ann. Myc. **18**: 70. 1920.

As Martin (**10**) has pointed out, this fungus, sometimes mistaken for an *Auricularia*, is referable to *Phlebia*.

Auricularia tabacina Sowerby, Ill. Eng. Fungi **1**: 1796.

This species is described by Sowerby as having a "light yellow margin being contrasted with the bright and often nearly red-brown of the upper and under side."

Auricularia totarae Lloyd, Myc. Writ. **6**: 935. 1920.

I have examined the type of this species and have determined it as an *Exidia*.

Auricularia venulosa Fries, Nov. Act. Soc. Upsal. III, **1**: 113. 1851.

Berkeley identified this species as a *Phlebia* and until type material can be found it should be excluded from *Auricularia*.

NOMINA NUDA

Auricularia inconcinum (Cke.) Farlow, Bibl. Index. 1905.

Farlow has the following comment regarding this species. "The name *Stereum inconcinum* of Herb. Berkeley, apparently a manuscript name, is said by Cooke, 1891, to be an *Auricularia*." Farlow gives no diagnosis.

Auricularia undulata Fries, Syst. Orb. Veg. 82. 1825.

Fries lists this species as new but it is not accompanied by a description.

SUPPLEMENTARY NOTE: A paper by M. A. Donk, in Reinwardtia **1**: 487–500. 1952, entitled "Notes on Malesian Fungi II. On the genera *Auricularia, Hirneola* and *Laschia*," came to my attention after the manuscript of this paper had gone to the printer.

Donk once again gives his reasons for favoring the conservation of *Hirneola* Fries 1849 and suggests that *Laschia* Fries 1830 be included, at least provisionally, within it. In anticipation of the conservation of *Hirneola*, a new combination, *H. nigricans* (Sw. ex Fr.) (= *Auricularia polytricha* (Mont.) Sacc. of this paper), is proposed. As pointed out by Rogers (Farlowia **3**: 448–449. 1949), *Peziza nigricans* Sw., reported by its author as occurring "on the ground," is not an acceptable type. However, in support of his contention that *Hirneola* should be conserved, Donk revives the Fresian concept which emphasizes the difference between *Hirneola* and *Auricularia* based upon what Donk recognizes to be the "only partly correct" assertion that the position of the hymenophore of *Hirneola* is superior whereas that of *Auricularia* is inferior. Opinions differ among some mycologists as to whether this assertion is partly correct or wholly incorrect, my own judgment favoring the latter more than the former. Although Donk states that this distinction is "of little generic value," he adduces

other reasons to show that in the opinion of Fries, at least, there was sufficient justification for considering the genera in question to be separate at that time.

Donk believes that a genuine separation between *Hirneola* and *Laschia* is still more difficult to make, since "the generic limits between *Hirneola* and *Laschia* are somewhat effaced by species intermediate in certain respects." In fact, it remains a matter of conjecture as to the manner in which *Laschia* and *Auricularia* differ and the view taken in this paper is that *Laschia* should be included in *Auricularia*.

I am in accord with Donk in maintaining that the precise position of a taxon within a taxonomic framework often depends upon the opinions of individual botanists, and because of this conviction I cannot agree that the expression of these differences by "mycologists sharing Roger's taxonomical views" should be construed as a hinderance to the better understanding of this particular nomenclatural problem.

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A REVIEW OF THE LEPTOGRAPHIUM—SCOPULARIA—HANTZSCHIA NOMENCLATURE[1]

CHARLES GARDNER SHAW[2] AND ERNEST E. HUBERT[3]

(WITH 3 FIGURES)

Recent reports issued by the Division of Forest Pathology, United States Department of Agriculture (**7**, **8**), by the University of Idaho (**1**), and by the Laboratory of Forest Pathology, Victoria, B. C. (**19**), have drawn attention to the common occurrence of blue-staining organisms of the *"Scopularia—Leptographium"* type on western white pine (*Pinus monticola* Dougl.). These articles have also pointed out that fungi causing blue stain have been found associated with symptoms typical of pole blight (**26**). The occurrence of similar fungi on both hardwoods and conifers has also been noted by many other workers (**6**, **24**, **28**).[4]

Increasing interest in these fungi makes it desirable that the nomenclature of the imperfect stages be brought into conformity with the International Rules of Botanical Nomenclature (**3**). This is especially necessary since: (a) the perfect stages are not known for all species involved, (b) in those species for which perfect stages are known often only the imperfect stages are encountered and (c) isolations frequently yield only the imperfect stages.

Scopularia venusta Preuss was described (**20**) and illustrated (**21**, *Taf. 64*) in 1851. Preuss's illustration, which has been repeatedly reproduced (**10**, **12**, **15**), appeared in a separate publication from that which contained the written description. Because

[1] Scientific Paper No. 1074. Washington Agricultural Experiment Stations, Pullman. Project No. 1025.

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[4] Additional references to fungi of this type are included in the citations given in the list of synonyms.

later workers (**10, 14**) have, in most instances, referred to Saccardo's description (**25**, p. 330) rather than to the original description, the latter is reproduced here.

"*Scopularia* Preuss.

"Acervulis minutissimis punctiformibus nigris epi- et entoxylinis; stipite erecto simplici, apice pallido, albido, saepe ramoso, ramulosove, seu floccoso et penicillatim diviso, capitulum ovatum formante; sporis ovoideis albis.

"Habitat in ligno Pini excorticatae.

"116. *S. venusta.* Hyphopodium repens ramosum s. lignum penetrans septatum; stipes subsimplex erectus, septatus, supra capitatus, penicillato-ramoso-ramulosus, ramulis continuis, strato mucoso primum tectus. Sporae acrogenae coacervatae simplices subheterogeneae" (**20**, p. 133–134).

If Preuss had published only the above description there might have been less difficulty in interpreting *Scopularia venusta*. The illustration has been responsible for much of the confusion concerning this species.

Saccardo, in listing this species, rewrote the description, basing it both on Preuss's description and illustration. The expression "ramulis oppositis basi, vaginato-connatis continuis" (**25**, p. 330) originated with Saccardo, not with Preuss, to whom it is credited by Goidànich (**10**) at a later date. Saccardo indicated that he doubted the accuracy of Preuss's illustration by actually writing ". . . basi (simulate?), vaginato-connatis. . . ." The description given by Lindau (**15**) is also based on both Preuss's illustration and description.

A second species, *S. Clerciana*, was described by Boudier (**4**) in 1901. Von Höhnel (**13**) considered this species similar to and perhaps identical with *Gliosphaera globuligera* v. Höhnel. He made the new combination *G. Clerciana* (Boud.) v. Höhnel. Lindau (**15**) treated this species similarly. Goidànich (**10**), however, later disagreed with this disposition of Boudier's species, maintaining it as *Scopularia Clerciana* Boud.

In 1927 Lagerberg, Lundberg and Melin erected the new genus *Leptographium* primarily because the characters previously ascribed to *Scopularia* could not be verified. Their discussion (**14**, p. 256) suggests that they also worked with the modified descriptions by Saccardo and Lindau. A single species, *L. Lundbergii* Lagerberg

& Melin, was described with the comment "Forsan *Scopulariae venustae* Preuss synon." (**14**, p. 257).

In 1931, Grosmann (**11**) described a second species of *Leptographium* and the next year (**12**) reported its perfect stage. In the second paper she reviews the literature concerning *Leptographium* and *Scopularia*, bringing *Hantzschia phycomyces* Auerswald into the discussion.

Grosmann was sufficiently convinced that *Leptographium* Lagerberg and Melin and *Hantzschia* Auerswald were synonyms to make a new combination, *Leptographium phycomyces* (Aws.) Grossman; nevertheless she said that the genus *Leptographium* need not be stricken "weil die diagnose Auerswalds sehr unzureichend ist"!! (**12**, p. 193).

Goidànich (**9**) the next year presented reasons for using *Scopularia* and described an additional species in that genus. However, other authors continued to use the genus *Leptographium*. This prompted Goidànich in another paper (**10**) to amplify his reasons for accepting *Scopularia* instead of *Leptographium*. He pointed out that at low magnification there is considerable resemblance between his *Scopularia serpens* and Preuss's illustration. If not examined too carefully, it could be interpreted as illustrated by Preuss. He therefore concluded that *Scopularia* and *Leptographium* were synonymous.

Goidànich's reasons are sound in every respect except one, namely that *Scopularia* Preuss is a later homonym of *Scopularia* Lindley (**16**). This fact was evidently not known by Goidànich. Nevertheless, Nieuwland (**18**) first called attention to these homonyms in 1916. [See also Rogers (**22**, **23**).] Nieuwland did not determine if another generic name was available, but merely proposed *Lindavia* Nieuwland in place of *Scopularia* Preuss. Simultaneously Nieuwland suggested *Outhovia* if for some reason *Lindavia* should prove unsatisfactory.

Scopularia Lindl. was first published in volume 20 of Edwards Botanical Register in 1834. The Latin description of the genus appears on an unnumbered page following *pl. 1702* (**16**). A single species, *S. Burchellii*, is listed as belonging in the genus, but is not described in this publication. A year later the same generic de-

scription was republished (**17**); in this publication there is also a description of the species, *S. Burchellii*.

Even though *Scopularia* Lindley is listed among the rejicienda (**22**) in Kew Bul. Mis. Inf. **1940**: 96, *Scopularia* cannot be used "for a group of the same rank based on a different type" [(**3**) Art. 61].

Subsequent to Preuss, *Hantzschia phycomyces* Auerswald was the first binomial applied to a fungus of the type under discussion. Portions of the original collection were distributed in Rabenhorst's Fungi Europaei (No. *441*) and the fungus was discussed and excellently illustrated elsewhere (**2**). Since the specimen may not be available to all those interested in the problem, the printed label is reproduced here.

"Rabenhorst, Fungi europaei
"441. Hantzschia Awd. Nov. Sporocybaceorum genus. Hedwigin N. 10. T. XI
"Floccis sterilibus ramosis, eseptatis, decumbentibus, pannoso-intertextis; fertilibus erectis, simplicibus, septatis, apice in pseudovesiculam apophysatam transeuntibus; sporis ovalibus, simplicibus, albis sporophoris longissimis, pseudovesiculam inplentibus suffultis.
Hantzschia Phycomyces Awd.
Floccis sterilibus tenerrimis, fuscis, Rhacodium cellare fere simulantibus; fertilibus 1–3 septatis, apice incrassatis; pseudovesicula albida, absque ulla membrana peripherica non nisi e sporis leniter conglutinatis formata.
Hab. in Cryptis supra ligna latas plagas formantia.
Figura *Phycomycis nitentis* Kz. (Myc. Hefte II. Tab. II. fig. 9.) non male cum pseudovesicula *Hantzschiae* quadrat. Dolendum ext quod totum genus *Phycomycis* in herbario academico lipsiensi (Kunzeano) non extat, ita ut nunc non discernendum sit, nunc sporae in genere Phycomyce revera vesiculae sint impositae, aut etiam, ut in *Hantzschia* nostra, sporophoris suflultae.
(Auerswald.)
Dresdae leg. C. A. Hantzsch."

This description, except for the last line, was later reproduced exactly as it appeared on the original label in the Botanische Zeitung **20**: 198. 1862.

Examination of the type collection (see FIG. 1, 2) discloses the presence of the fungus, *Hantzschia phycomyces* Awd. The material we have examined (received on loan from the cryptogamic

herbarium of the University of Wisconsin through the courtesy of H. C. Greene) agrees exactly with the illustrations published by Auerswald (**2**, *Tab. XI*) and is certainly congeneric with the material we have seen on western white pine (FIG. 1, 3) and lodgepole pine (*Pinus contorta* Doug. var. *latifolia* Engelm.). Other fungi are present in the fungous mat comprising the type specimen; this

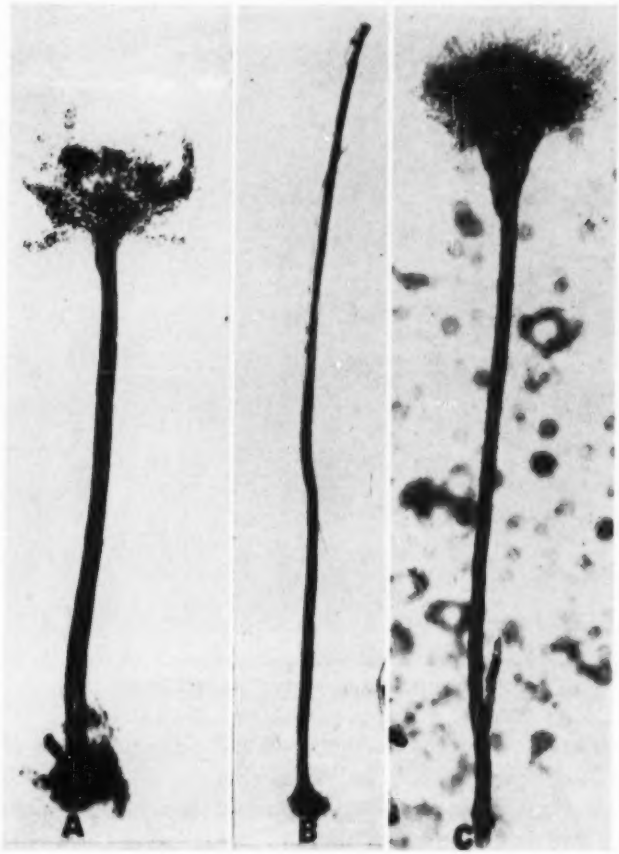

FIG. 1, A, B. Conidiophores of *Hantzschia phycomyces* Awd. Head broken off in (B) but note primary branching. From the TYPE, Rabenhorst, *Fungi europaei* No. *441* (A, × 250; B, × 110). C. Conidiophore of *Leptographium* sp., isolated from *Pinus monticola* Dougl. Hubert Isolate No. *77*, × 160.

is only to be expected in material such as this collected on oaken kegs stored in damp cellars. From Auerswald's illustrations there can be no question concerning the fungus to which he applied the name *Hantzschia phycomyces*. Wollenweber and Stapp (**27**) examined the portion of the type in the Botanical Museum at Berlin-Dahlem and published original illustrations (**27**, *Tab. III, G*)

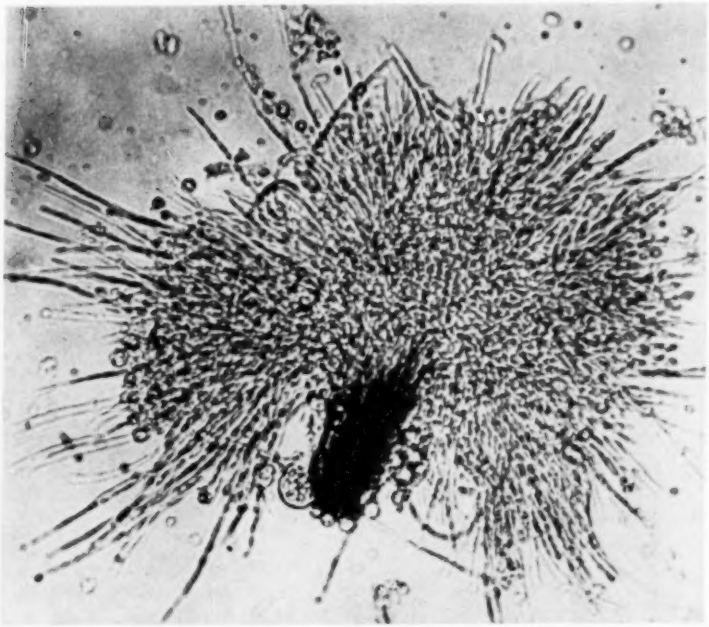

FIG. 2. Conidiophore head of *Hantzschia phycomyces* Awd. from the TYPE, Rabenhorst, *Fungi europaei* No. *441*, × 940.

which agree with those of Auerswald and with our figures (FIGS. 1–3).

Acceptance of the generic name *Hantzschia* would necessitate the transfer of those species described in *Scopularia* and *Leptographium* to this genus. However, Wm. Bridge Cooke has called to our attention that *Hantzschia* Grunow [Monthly Micro. Jour. (Trans. R. Micr. Soc.) **18**: 173–174. 1877] is in current usage for a genus of diatoms (Bacillarieae, Pennales, Nitzschiaceae). Algologists

have used the name in this sense in good faith for many years. Numerous species have been assigned to *Hantzschia* Grunow, while *Hantzschia* Auerswald has had only the type species, *H. phycomyces* Auerswald, assigned to it. Of lesser importance, but nevertheless worthy of consideration, is the fact that undoubtedly a majority of mycologists and forest pathologists would prefer to use *Leptographium* for the fungi involved. Consequently, even though

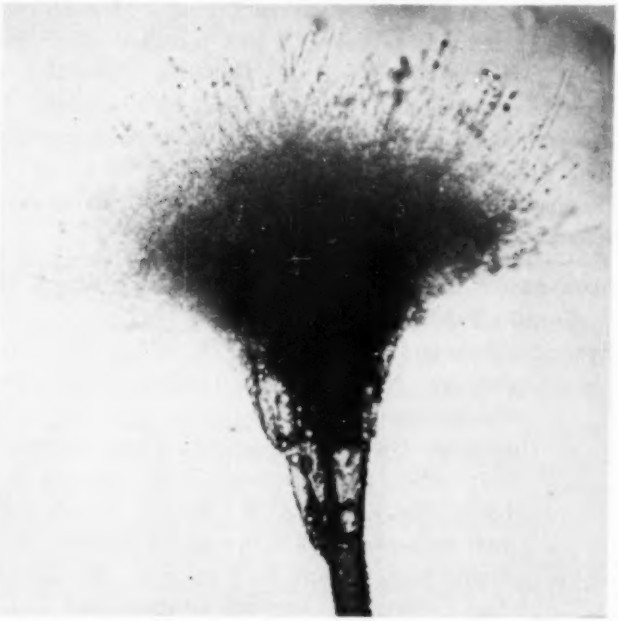

FIG. 3. Conidiophore head of *Leptographium* sp., isolated from *Pinus monticola* Dougl. Hubert Isolate No. 77, × 470.

Hantzschia Grunow is a later homonym of *Hantzschia* Auerswald, there are excellent reasons for proposing the conservation of *Hantzschia* Grunow against *Hantzschia* Auerswald. For these reasons it is proposed that *Hantzschia* Grunow be conserved and *Hantzschia* Auerswald be rejected.

Our attempts to locate a type of *Scopularia venusta* Preuss have been unsuccessful. J. A. Nannfeldt, in personal correspondence,

informs us, "I have also on several other occasions come into contact with species described by Preuss, but I have never had an opportunity to see one of his types. Nor have I in the literature found a note about such specimens, and so I am convinced that they are no longer in existence or at least that their location is totally forgotten."

In the absence of a type specimen, there must always be uncertainty concerning the fungus to which Preuss applied the binomial *Scopularia venusta* Preuss. *Scopularia* Preuss is therefore a *nomen dubium* [(**3**) Art. 63] as well as a later homonym of *Scopularia* Lindley. *Lindavia* Nieuwland and *Outhovia* Nieuwland, since based on the same type as *Scopularia* Preuss, are also *nomina dubia*.

Leptographium Lagerberg and Melin then becomes available for the fungi under discussion.

The synonymy involved is listed below without making any new combinations at this time.

LEPTOGRAPHIUM Lag. & Melin in Lagerberg, Lundberg & Melin, Svenska Tidskrift **25**: 257. 1927.

Syn.: ?*Scopularia* Preuss, Linnaea **24**: 133. 1851. *Nomen dubium*. Not *Scopularia* Lindley. 1834. *Nomen rejiciendum*.

Hantzschia Awd. in Rabenhorst, Fungi europaei No. *441*. 1862. [Also Hedwigia **2**: 60; *Tab. XI, fig. a–f.* 1863. Bot. Zeit. **20**: 198. 1862.] *Nomen rejiciendum propositum*. Not *Hantzschia* Grunow, Monthly Micro. Jour. (Trans. R. Micr. Soc.) **18**: 173. 1877. Also Grunow in Cleve and Grunow, Beit. z. Kennt. Arct. Diatomeen: 103. 1880. *Nomen conservandum propositum*.

?*Lindavia* Nieuwl. Amer. Midl. Nat. **4**: 384. 1916. *Nomen dubium*.

Type species: *Leptographium Lundbergii* Lag. & Melin.

1. *Leptographium Lundbergii* Lag. & Melin in Lagerberg, Lundberg & Melin, Svenska Tidskrift **25**: 257. 1927.

Syn.: *Scopularia Lundbergii* (Lag. & Melin) G. Goid. Ann. Myc. **31**: 138. 1933.

2. *Graphium tenuissima* Corda, Icones Fungorum **1**: 19. 1837.
Syn.: *Haplographium tenuissimum* (Corda) Grove, Hard. Sci. Gossip **1885**: 198. 1885.
Scopularia tenuissima (Corda) G. Goid. Annali di Bot. **21**: 49. 1935.

3. ?*Scopularia venusta* Preuss, Linnaea **24**: 134. 1851. *Nomen dubium.*
Syn.: ?*Lindavia venusta* (Preuss) Nieuwl. Amer. Midl. Nat. **4**: 385. 1916. *Nomen dubium.*

4. *Hantzschia phycomyces* Awd. in Rabenhorst, Fungi europaei No. *441.* 1862. [Also Hedwigia **2**: 60; *Tab. XI, fig. a–f.* 1863. Bot. Zeit. **20**: 198. 1862.]
Syn.: *Graphium phycomyces* (Awd.) Sacc. Syll. Fung. **4**: 614. 1886.
Leptographium phycomyces (Awd.) Gros. Hedw. **72**: 193. 1932.

5. *Scopularia Clerciana* Boud. Bull. Soc. Bot. Fr. **48**: 112; *Tab. II, fig. II.* 1901.
Syn.: *Gliosphaera Clerciana* (Boud.) v. Höhnel, Sitzber. Kais. Ak. Wiss. Wien. Math. Nat. Kl. **111**: 1038. 1902.

6. *Scopularia populi* Dearness & Bisby in Bisby, Buller & Dearness, Fungi of Manitoba 130. 1929.

7. *Leptographium penicillata* Grosmann, Zeitschr. f. Parasitenkunde **3**: 94. 1931.
Syn.: *Scopularia penicillata* (Gros.) G. Goid. Boll. Staz. Patol. Veg. Roma N. S. **15**: 156. 1935.
Perfect stage is *Grosmannia penicillata* (Gros.) G. Goid. Boll. Staz. Patol. Veg. Roma N. S. **16**: 46. 1936.

8. *Scopularia scopula* G. Goid. Ann. Myc. **31**: 137; *Tav. III, fig. 1–4.* 1933.

9. *Leptographium microsporum* Davidson, Jour. Agr. Res. **50**: 805. 1935.
Syn.: *Scopularia microspora* (David.) G. Goid. Boll. Staz. Patol. Veg. Roma N. S. **16**: 38. 1936.

10. *Scopularia serpens* G. Goid. Boll. Staz. Patol. Veg. Roma N. S. **16**: 42. 1936.

Syn.: *Leptographium serpens* (G. Goid.) Siemaszko, Planta Polon. **7** (3): 34. 1939.

Perfect stage is *Grosmannia serpens* G. Goid. (l. c.).

11. *Scopularia pini* G. Goid. Boll. Staz. Patol. Veg. Roma N. S. **16**: 49. 1936.

Perfect stage is *Grosmannia pini* (Münch.) G. Goid. Staz. Patol. Veg. Roma N. S. **16**: 48. 1936.

12. *Scopularia Rumboldii* G. Goid. Boll. Staz. Patol. Veg. Roma N. S. **16**: 51. 1936.

Perfect stage is *Grosmannia ips* (Rumb.) G. Goid. Boll. Staz. Patol. Veg. Roma N. S. **16**: 51. 1936.

13. Imperfect stage of *Ceratostomella piceaperda* Rumbold, Jour. Agr. Res. **52**: 436. 1936.
14. Imperfect stage of *Ophiostoma polonicum* Siesmaszko, Planta Polonica **7** (3): 32. *Plate IV*. 1939.
15. Imperfect stage of *Ceratostomella* (*Grosmannia*) *leptographioides* Davidson, Mycologia **34**: 657. 1942.
16. Imperfect stage of *Ceratostomella* (*Grosmannia*) *rostrocylindrica* Davidson, Mycologia **34**: 658. 1942.
17. *Scopularia corsicana* v. Beyma, Ant. v. Leeuw. Jour. Microbiol. & Serol. **10**: 45. 1944.
18. *Scopularia halepensis* Biraghi, Ann. Sper. Agr. (N. S.) **1**: 120. 1947.

Mention should also be made of the fungus found by Elliott (**5**) on the cones of *Pinus sylvestris*. She considered her material *Scopularia venusta*. However, she observed conidia with two septations. Septate conidia have not been reported by other workers in any of the species listed above. We have not encountered septate conidia in many hundreds of cultures of *Leptographium*, even though spore germination has been repeatedly observed for many of our isolates. For these reasons Elliott's material is not considered to belong in the genus *Leptographium*.

The color of the conidia and of the ultimate and penultimate branches of the conidiophores seems to be the primary distinction between *Leptographium* and *Haplographium* Berk. & Br. The conidia of *Haplographium delicatum* Berk. & Br., the type species, are described as dark in color. Other species included in *Haplo-*

graphium, such as *H. bicolor* Grove, *H. fuscipes* (Preuss) Sacc., etc., are described as having hyaline conidia. Such species might logically be transferred to *Leptographium*. However, the list above is limited to species already treated in the literature as belonging in *Hantzschia, Scopularia, Leptographium*, or as the imperfect stages of the Ascomycetous genus *Grosmannia*.

We wish to express our appreciation to Mr. John Stevenson of the U. S. Bureau of Plant Industry, Soils, and Agricultural Engineering for reviewing the manuscript and making available to us a translation of Goidànich's important paper (**10**). Thanks are also due William D. Yerkes, Jr., for the photomicrographs.

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FURTHER NOTES ON CRYPTOMYCINA PTERIDIS [1]

SARA BACHE-WIIG

In an earlier paper by the writer (**1**) the systemic nature of the infection of bracken (*Pteridium latiusculum* (Desv.) Hieron. ex R. E. Fries) with *Cryptomycina Pteridis* (Rebent. ex Fries) v. Höhn. was established for plants showing the characteristic stiffness and curling of young fronds followed by the eventual development of abundant, regularly distributed stromatic areas superficially resembling *Asplenium* sori. It was also demonstrated that in fronds showing only scattered lesions of varying size the invading fungus was localized and remained so. For the inoculations reported upon in that study, conidia only were used. The present note concerns observations upon and experiments with ascospores.

As reported first by Fuckel (**2**) and studied in detail by Killian (**3**) the ascospores mature in spring and early summer on dead, overwintered fronds, whereas conidia are produced over a long period in summer and fall, even continuing to be formed, along with the asci, on the overwintering frond (**2, 1**). The conidial mass is glutinous, occurring as ooze or as cirrhi.

GERMINATION OF ASCOSPORES

Killian (**3**) tried to induce ascospore germination. He obtained spores by shaking up pinnules of overwintered bracken showing opened pseudothecia in water in a test tube. His trials with liquids, decoctions and sugar solutions he reports only as altogether variable (". . . die Keimung ganz unbeständig ausfiel"). Nor was any germination observed by him when drops of water containing ascospores were placed on pinnules from living fronds, kept in moist chambers. In the writer's experience, also, germination of ascospores proved variable, as had previously been found true of

[1] Contributions from the Department of Botany, Smith College, new series No. 45.

conidia (1). Good germination was obtained, however, in sterile distilled water on slides in moist chamber at room temperature by the crude method of using scrapings from the surface of opened pseudothecia. By the same method, germination was also obtained in filtrate of young bracken pinnae crushed in distilled water. In addition to ascospores the scrapings contained asci, conidia, fragments of pseudothecia and extraneous material, and were obviously unusable as inoculum.

INOCULATION EXPERIMENT

After failure to obtain ascospores on the covers of sterilized Petri plates in which soaked overwintered fronds with mature pseudothecia had been placed, the following method of obtaining inoculum was resorted to: strips of chromium wire netting were placed across an uncovered Petri plate, and portions of pinnae, pseudothecia down, were placed across the netting, bridging the spaces between strips. The open plate was left in an uncovered crystallizing dish. About 12 hours later the frond pieces and wire netting were removed and a few fragments that had broken off as the pinnules dried and curled were picked out of the plate. Sterile distilled water was then swished over the bottom of the plate. It was feared that the fragments might have contaminated the inoculum with conidia, but examination of a sample of the suspension showed hundreds of ascospores and no typical living conidia. This ascospore suspension was therefore used as inoculum.

Drops of inoculum were placed by means of a pipette on the upper surface of a young bracken frond previously sprayed with sterile distilled water. The frond had the lower pair of pinnae mostly unrolled and the second pair in process of expansion. By means of a sketch, a record was kept of the location of the drops of inoculum. Another young frond in the same flat was used as a control, being sprayed with sterile distilled water. Each frond together with an adjacent vial of water was covered by an inverted glass vessel. The flat of bracken used in this experiment was green-house grown, from healthy stock.

Some of the inoculated portions of the frond were cut in pieces and fixed after 25 hours, 29 hours, 3 days and 4 days.

Examined 16 days after inoculation the inoculated segments showed brown areas similar to the localized lesions resulting from artificial inoculation with conidia (1). When the frond was picked, after 20 days, typical conidial cirrhi were found on the lower surface of the brown spots. The conidia making up the cirrhi were in general typical in form and size of *Cryptomycina Pteridis*. A few much shorter conidia were present.

The control frond remained healthy.

Microscopic examination of stained slides made from the inoculated frond portions fixed 25 and 29 hours after inoculation showed many ascospores attached to the surface of the frond. Some of the ascospores had germinated. The beginning of penetration of the epidermal wall was observed.

Examination of material fixed 3 days after inoculation showed that a rapid invasion of the host cells below the point of penetration had taken place. The fungus was found as deep in the mesophyll as the 5th cell from the surface. The mycelium is well developed and mostly intra-cellular. At this stage the mesophyll cells in general present a normal appearance except for the presence of the parasite.

In all the points observed in the fixed material—rapidity of invasion of the host cells by the parasite, aspect and distribution of the fungous mycelium, and lack of disorganization in the newly invaded cells—the picture presented by ascospore infection corresponds to that shown by conidial infection.

DISCUSSION

Since ascospores are shown to be capable of producing localized lesions in young bracken fronds of mature plants, it may be concluded that early-developed fronds showing such symptoms in the field have become diseased as a result of inoculation by ascospores.

Since there appears to be no difference between ascospores and conidia in their capacity to infect young fronds of mature plants, it may be assumed that ascospores also, as the writer (1) has demonstrated for conidia, can infect very young sporophytes of bracken and so initiate new systemic infections.

SUMMARY

Evidence is presented to show that infection of young bracken fronds of mature plants with *Cryptomycina Pteridis* may be caused by ascospores as well as by conidia as demonstrated in an earlier study. The symptoms of disease following inoculation with ascospores are similar to the localized lesions resulting from inoculation with conidia. The production of conidial cirrhi is alike in the two cases. Microscopic study reveals the same rapid invasion of the host tissues and similarity in the invading mycelium and in the appearance of the host cells.

The role of ascospores in the life history of the parasite is discussed.

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NORTHAMPTON, MASSACHUSETTS

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HEINRICH SANDSTEDE (1859–1951)

GEORGE A. LLANO

(WITH PORTRAIT)

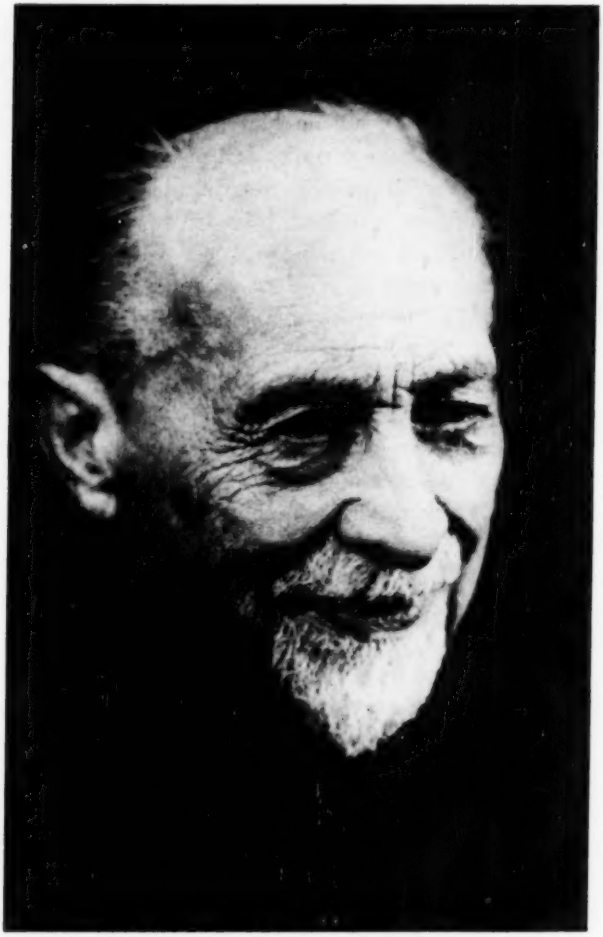
Heinrich Sandstede's death on March 5, 1951, brought to its close a long life of restless curiosity and of boundless enthusiasm for his work. It was his privilege to span a period of lichenology rich in skilled workers. All were beholden to him for his adept studies; future students will feel their debt to him for the thousands of specimens which he generously gave to herbaria throughout the world. Until his eyesight failed, and the end was near, he worked steadily. "Preparedness is everything!" he used to say.

Heinrich Sandstede was born in Ganderkesee, a small town west of Bremen, Oldenburg Province, on March 20, 1859, the son of Gerhard Diederich, master baker, and Catarine Marie Hartel Sandstede. Both parents came of old and excellent families. Heinrich was the eldest of nine children, of whom six outlived him. About 1876 he set out as a journeyman baker, traveling in Alsace, Switzerland, Denmark, and western Germany. In 1885 he married Helene zu Klampers, who died in 1911; their two children died in 1946 and 1947.

From his earliest years Sandstede was a student of nature—self-taught and interested in taxonomy—of the flowering plants at first and the vascular cryptogams, and then to the mosses, hepatics, and lichens. About 1879 he met Franz Müller, school director of Varel. A specialist in mosses, Dr. Müller recognized a fellow botanist in the young baker. They worked together as cryptogamists of the Oldenburg Province flora and out of their studies grew Sandstede's specialization in lichens.

Circumstances limited Sandstede to local research; he roamed to every nook and corner of the region closest to home and in later years farther afield. His first reports were of the lowlands of Northwest Germany (1889–1903), later extended to studies of the lichens of the Friesian Islands (1893–1906), the Island of Neuwerk

(1903), Rügen (1906) and Heligoland (1894–1925). In the Rabenhorst series (1931) he contributed the section on the genus *Cladonia* for Germany, Austria, and Switzerland, following it with



HEINRICH SANDSTEDE, 1859–1951

a phytogeographical study of the Cladoniaceae in "Die Pflanzenareale" (1932–39) edited by Hanning and Winkler. Gradually he came into closer contact with the leading lichenologues of his day,

visiting and receiving visits and specimens from collectors and colleagues all round the world. At thirty he presented his first report, "Contributions to a Study of the Lichen Flora of the Lowlands of Northwest Germany" (1889); at 91 his last paper, "Changes in the Flora of the Immediate Vicinity of our Province" (1950), reveals his still keen appreciation of local floristic problems of his native Ammerländ.

Through local studies Sandstede gained the opportunity for the analysis of local habitats, important for a clear understanding of the myriad variations so common to *Cladonia* species. He was conservative in nomenclature, apt in his interpretation of biological and ecological data, and choice in the selection of exsiccati materials. In the taxonomy of *Cladonia,* Sandstede was undoubtedly influenced by Vainio's "Monographia Cladoniarum Universalis" (1887–1898), that classical study of the phylogeny with the first real systematic arrangement based wholly on the morphology of their specialized lichen thallus. With the introduction of Asahina's paraphenylendiamine tests in "Zur Systematik der Flechtenstoffe" (1934) and simple microchemical methods, it became possible to distinguish the variations of *Cladonia* not only by morphological differences but by differences in substances which they produced. Sandstede grasped the significance of Asahina's methods and applied it to Vainio's system, in the report "Ergänzungen zu Wainio's Monographia 'Cladoniarum universalis' unter besonderer Berücksichtigung des Verhaltens der Cladonien zu Asahina's Diaminprobe" (1938). Asahina's work was something more than a scientific report to Sandstede; it was a personally uplifting and joyful fact which his warm nature could not pass in cold scientific words. "As I learned about it, I could not refrain from writing to a botanical friend with strong feelings of elation: Three hurrahs for Asahina!"

From 1889 on, Sandstede was able to devote himself almost wholly to lichenology. In 1912, at the age of 53, he began to work intensively with *Cladonia.* In 1917 he began the first edition of *Cladoniae exsiccatae* (1918–1929), and was an acknowledged master of the genus, sharing the honor with Vainio of Finland until the latter's death in 1929. The *Exsiccatae* appeared in 13 fascicles of 1886 species and forms which he freely distributed to 50 museums, botanical institutes and to his colleagues. He revised nu-

merous *Cladonia* collections, including that of the Berlin-Dahlem Museum, and the famous collections of Müller-Argau at the University of Geneva. His own herbarium, exclusive of *Cladonia*, was presented to the Museum of Bremen in 1912.

His scholarship and industry won him honor at home. He was elected honorary member of the Scientific Society of Natural Sciences of Bremen, of the Society of Natural Sciences of Oldenburg, of the Botanical Society of Brandenburg; member of the Kaiser Leopold German Academy in Halle, and was a corresponding member of the Bavarian Botanical Society. For his research on the flora of Central Europe he was granted the Acherson plaque. The Oldenburg Medal, 1st class, was awarded him at 38, by the Grand Elector Nikolaus Friedrich Peter for his studies on the "Lichens of Oldenburg." In 1930, on his 71st birthday, the University of Münster presented Sandstede with "the title, the rights and privileges of Honorary Doctor of Philosophy," characterizing him as: "The outstanding authority on the North German lichen world, the researcher who is known far beyond the German boundary for his studies in the manifold Cladonias, the unselfish searcher of indispensable herbal materials and scholar . . . in the field of lichen research."

Sandstede was honored by his colleagues in six new lichen species: *Verrucaria Sandstedei* by Bouly de Lesdain of Dunkirk; *Cladonia Sandstedei* by des Abbayes of Rennes; *Stagonospora Sandstedeana* by Keissler of Vienna; *Parmelia Sandstedeana* by Gyelnik of Budapest; *Diplodia Sandstedei* by Zopf of Münster; and *Lecidea Sandstedei* by Zwackh of Heidelburg.

Sandstede's love for nature and for his homeland were inseparable. He was proud of his North German inheritance, an Ammerländer with a preference for the Low German speech of his province and with a strong attachment for local customs and folklore. He devoted much time to provincial activities, assisting in founding the Freiland Museum (1909) and in restoring the Ammerländ Peasant Farm and an Oldenburg village, popular as a bathing beach, which provided a suitable background for yearly pageants of the life and festivals of his Ammerländer neighbors. In May, 1927, during one of these festivals, Sandstede was honored by a visit from President Hindenburg. A photograph of the occasion shows Sand-

stede as of medium height and slight build, dressed in dark garb with a full silver-buttoned waistcoat, short coat and breeches, wearing gaiters and old-fashioned silver-buckled shoes.

He was an authority on antiquarian lore and through 65 years he published many articles in the newspaper "Ammerländer" and "Nachrichten für Stadt und Land," and in a monthly periodical "Niedersachsen." For his contributions in this field he was honored with membership in the Society for Folkways of Lower Saxony (Bremen), in the Oldenburg Regional Society for History and Native Lore, and in the Regional Union of Lower Saxony (Hannover).

He was proud of his trade and full of reminiscences of his early training, which he described with humor in numerous stories from 1930 on in a small trade journal "The Bakers' Little Adviser." "Lena wants to Bake" and "Apprentice Pranks" were stories to amuse the younger generation but "Bread Substitutes in Times of Famine" (1930) was a neighborly contribution suggesting the economic use of lichens in harsher times.

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The author is indebted to the following persons: to Dr. I. Mackenzie Lamb, Ottawa, Canada, who kindly furnished the "Sonntagsbeilage . . ." sketch loaned to him by Mr. Fritz Sandstede, Buenos Aires, Argentina; to Dr. A. W. Evans, New Haven, Conn., for the "Ammerländer" woodcut and a photograph; to Mrs. Schröder-Sandstede for detailed correspondence and the photograph which illustrates this paper, and to Dr. Carroll W. Dodge and Miss Nell Horner of the Missouri Botanical Garden, St. Louis, for assistance with the bibliography.

AIR UNIVERSITY,
MAXWELL AFB, ALABAMA

NOTES AND BRIEF ARTICLES

The annual foray of the Mycological Society of America, 1951

The Botany Department of the University of Vermont at Burlington was host for the annual foray on June 19 to 21. Dr. Thomas Sproston, ably assisted by Miss Susan Lane and Mr. John K. Pollard, Jr., provided the attending members with excellent accommodations.

The following fungi were collected. The collectors reporting them are indicated as follows:

[MF]—Mycological Foray.
[RP]—Rene Pomerleau.
[SMP]—S. M. Pady.
[RFC]—R. F. Cain.

Myxomycetes: *Arcyria nutans* (Bull.) Grev. [MF], *Ceratiomyxa fruticulosa* (Muell.) Macbr. [SMP], *Didymium melanospermum* (Pers.) Macbr. [RP], *Didymium squamulosum* (Alb. & Schw.) Fr. [RP], *Fuligo septica* (L.) Web. [MF], *Hemitrichia vesparium* (Batsch) Macbr. [MF], *Lycogala epidendrum* (L.) Fr. [SMP], *Physarum nutans* Pers. [RFC], *Stemonitis ferruginea* Ehr. [MF].

Ascomycetes: *Aleuria aurantia* (Pers.) [MF], *Bifusella faullii* Darker on *Abies balsamea* [RFC], *Botryosphaeria fuliginosa* (Moug. & Nest.) Ell. & Ev. [RP], *Cordyceps militaris* Lk. [MF], *Dermea cerasi* (Pers. ex Fr.) Fr. on *Prunus serotina* [RFC], *Diaporthe eres* Nits. [RP], *Diatrype albopruinosa* (Schw.) Cke. [RP], *Diatrype stigma* (Hoffm.) Fries [RP], *Diatrypella betulina* Pk. on Betula [RFC], *Dibotryon morbosum* (Schw.) Th. & Syd. on *Prunus* [RFC], *Eutypella parasitica* Lor. & Dav. [RP], *Helotium immutabile* Fckl. [MF], *Hypoderma commune* (Fr.) Darby [MF], *Hypodermella mirabilis* Darker [RP], *Hypodermella nervata* Darker on *Abies balsamea* [RFC], *Hypomyces aurantius* (Pers.) Tul. on *Polyporus* [RFC], *Hypoxylon cohaerens* (Pers.) Fr. [RP], *Hypoxylon coccineum* Bull. [RP], *Hypoxylon multiforme* Fr. on *Betula* [RFC] [RP], *Hypoxylon pruinatum* (Klotsch) Cke. [RP], *Lachnella agassizii* (Berk. & Curt.) Seaver on *Abies balsamea* [RFC] [RP], *Lachnum pygmaeaum* Bres. [MF], *Lamprospora brevispinosa* Seaver [RP], *Lophodermium macrosporum* (Hartig) Rehm on *Picea rubens* [RFC] (First report from N. America, causing considerable damage to foliage of host on slopes of Mt. Mansfield, Vt.), *Lophodermium piceae* (Fckl.) Hoehn. on *Picea rubens* [RFC], *Massaria inquinans* (Tode) Fr. [RP], *Mitrula phalloides* (Bull.) Chev. [RFC] [RP], *Mollisia cinerea*

(Batsch) Karst. on *Acer* [RFC] [RP], *Monilinia fructicola* (Wint.) Honey, *Patella scutellata* (L.) Morg. [MF], *Peziza badia* Pers. [RFC] [MF], *Peziza pustulata* (Hedw.) Pers. [MF], *Peziza vesiculosa* Bull. [RP], *Phacobulgaria inquinans* (Pers.) Nannfl. on *Quercus* [RFC], *Pleospora herbarum* (Pres.) Rbh. [MF], *Sclerotinia bifrons* (Sacc.) Whetz. [RP], *Scoleconectria scolecospora* (Bref.) Seaver [RFC], *Scorias spongiosa* (Schw.) Fr. on aphids on *Alnus* [RFC], *Sphaerospora spinulosa* [MF], *Sporormia bipartis* Cain [RFC], *Sporormia leporina* Niessl. [RFC], *Stigmatea robertiani* Fr. [RFC] [MF], *Taphrina carnea* Johans. [RP], *Taphrina caerulescens* (Desm.

Left to Right: Top row: Sproston, Espenshade, White, Cutter, Jackson. Second row: Reese, Turnau, Lowy, Johnson, Raymond, Wolff. Third row: Mrs. Scott, Miss Reese, Mrs. Reese, Carter, Wells, Hunter, Horner, Mrs. Snell, Mrs. Jackson, Mrs. Walters, Mrs. Lowy. Bottom row: Mrs. Gilman, C. W. Dodge, Snell, Gilman, Walters, Pomerleau, Pady, Cain.

et M.) Tul. [RP] [SMP], *Taphrina filicina* (Rostr.) Johans. [SMP], *Taphrina polystichi* Mix [RFC] [RP], *Ustilina vulgaris* Tul. [SMP], *Valsa leucostomoides* Pk. [RP], *Venturia fimiseda* Mout. [RFC], *Vibrissea truncorum* (Alb. & Schw.) Fr. [RFC] [RP], *Xylaria polymorpha* (Pers.) Grev. [MF].

BASIDIOMYCETES—USTILAGINALES: *Cintractia caricis* (Pers.) Magn. on *Carex* [RFC] [RP].

UREDINALES: *Chrysomyxa empetri* (Pers.) Schroet. II on *Empetrum nigrum* [RFC], *Chrysomyxa ledi* (A. & S.) deBary [MF], *Chrysomyxa*

ledicola (Pk.) Lagerh. on *Ledum groenlandicum* [RFC] [SMP] [RP], *Chrysomyxa weirii* Jackson, III on *Picea rubens* [RFC] (Previous reports of this species in Eastern U. S. only from Tenn. and W. Va.), *Coleosporium solidaginis* (Schw.) Thuem., *Cronartium comptoniae* Arth. I on *Pinus ponderosa* [RFC] [RP] [SMP], *Cronartium comptoniae* Arth. II on *Myrica asplenifolia* [RFC] [SMP], *Cronartium ribicola* Fischer [MF], *Gymnoconia peckiana* (Howe) Trotter on *Rubus* [RFC] [RP] [SMP], *Melampsorella cerastii* (Pers.) Schroet. I on *Abies balsamea* [RFC], *Milesia polypodophilum* (Bell) Faull, II, III on *Polypodium virginianum* [RFC], *Puccinia caricis grossulariata* Arth. I on *Ribes* [RFC] [SMP], *Puccinia extensicola asteris* (Thuem.) Arth. on *Aster macrophyllum* [RFC], *Puccinia extensicola solidaginis* (Schw.) Arth. on *Solidago* [RFC], *Puccinia heucherae* (Schw.) Diet. on *Tiarella cordifolia* [RFC], *Puccinia rubigovera agropyri* (Erikss.) Arth. on *Thalictrum* [RFC], *Puccinia violae* (Schum.) Arth. on *Viola* [RFC], *Pucciniastrum mytilli* (Schum.) Arth. on *Vaccinium vitis-idae minus* [RFC], *Tranzschelia fusca* (Pers.) Diet. on *Anemone quinquifolia* [RFC], *Uromyces caladii* (Schw.) Arth. I on *Arisaema triphyllum* [RFC] [RP] [SMP].

EUBASIDII: *Aleurodiscus amorphus* (Pers.) Rbh. on *Abies balsamea* [RFC] [RP], *Amanitopsis vaginata* (Bull.) Roze [RP], *Boletinus pictus* (Pk.) Pk. [MF], *Boletus* (*Suillus*) *granulatus* L. [MF], *Boletus subvelutipes* Pk. [RFC] [RP], *Boletus* (*Xerocomus*) *subtomentosus* L. [MF], *Calocera cornea* Fr. [MF], *Clavaria aurea* Schaeff. [MF], *Clavaria pyxidata* Pers. [MF], *Collybia dryophila* Bull. [MF], *Collybia platyphylla* Fr. [MF], *Corticium investiens* (Schw.) Bres. [MF], *Corticium tulasnelloideum* Höhn. & Litsch. [RFC], *Daedalea confragosa* Pers. [SMP], *Exobasidium vaccinii* (Fck.) Woron. [SMP], *Favolus alveolaria* (DC.) Quél. [SMP], *Favolus canadensis* Kotz. [RP], *Fomes applanatus* (Pers.) Wallr. [RP], *Fomes conchatus* (Pers.) Gill. on *Fraxinus* [RFC] [RP], *Fomes connatus* (Weinm.) Gill. [RP], *Fomes fomentarius* (L.) Gill. [RP], *Fomes igniarius* (L.) Fr. [MF], *Fomes pinicola* (Swartz.) Cke. [RP], *Fomes scutellatus* (Scw.) Cke. [RP], *Ganoderma tsugae* Murr. [MF], *Herpobasidium filicinum* (Rostr.) Lind on *Phegopteris dryopteris* [RFC] [RP], *Hydnochaete olivacea* (Schw.) Banker [RFC], *Hymenochaete corrugata* (Fr.) Lév. [RP], *Hymenochaete tabacina* (Scw.) Lév., *Hypochnus fumosus* Fr. [MF], *Irpex cinnamoneus* Fr. [MF], *Irpex fuscescens* Schw. [SMP], *Laccaria laccata* Fr. [MF], *Lenzites saepiaria* (Wulff) Fr. [RP], *Marasmius rotula* (Scop.) Fr. [MF], *Mycena acicula* Schaeff. [MF], *Mycena epipterygia* Scop. [MF], *Mycena leaina* Berk. [MF], *Odontia aspera* (Fr.) Bourd. & Galz. [RP], *Odontia hydnoides* (Cke. & Mass.) Höhn. on *Acer* [RFC], *Omphalia campenella* Batsch [RP], *Omphalia gerardiana* Pk. [RP], *Pellicularia flavescens* (Bon.) Rog. [RFC], *Pellicularia vaga* (Berk. & Curt.) Rog. [RFC], *Peniophora cinerea* (Fr.) Cke. [RP], *Peniophora guttulifera* (Karst.) Sacc. [RP], *Peniophora longispora* (Pat.) Bourd. & Galz. [RFC], *Peniophora pinastri* Bourd. and Maire [RP], *Peniophora setigera* (Fr.) Höhn. & Litsch. [RFC], *Peniophora subalutacea* Karst. [RP], *Pleurotus ostreatus* Jacq. [MF], *Polyporus abietinus* Fr. [SMP], *Polyporus albellus* Pk. [MF], *Polyporus hirsutus* (Wulff.) Fr. [MF], *Polyporus betulinus* Fr. [MF], *Polyporus con-*

chifer (Schw.) Fr. [RP], *Polyporus elegans* (Bull.) Fr. [RP], *Polyporus cinnabarinus* (Jacq.) Fr. [MF], *Polyporus lucidus* (Leyss.) Fr. [RP], *Polyporus nidulans* Fr. [MF], *Polyporus paragamenus* Fr. [RP], *Polyporus perennis* (L.) Fr. [SMP], *Polyporus pubescens* (Schum.) Fr. [RP], *Polyporus schweinitzii* Fr. [MF], *Polyporus squamosus* (Huds.) Fr. [RP], *Polyporus tulipiferus* (Schw.) ex Overh. [RP], *Polyporus versicolor* (L.) Fr. [MF], *Poria laevigata* (Fr.) Cke. [RP] [SMP], *Poria obliqua* (Pers.) Bres. [MF], *Poria prunicola* (Murr.) Sacc. & Trott. [RP], *Poria subacida* (Pk.) Sacc. [RP], *Poria tsugina* (Murr.) Sacc. & Trott. [RP], *Poria versipora* (Pers.) Romell [MF], *Russula fallax* Schaeff. [MF], *Schizophyllum commune* Fr. [RP], *Sebacina calcea* (Pers.) Bres. [RP], *Sebacina incrustans* (Pers.) Bres. [MF], *Sebacina mesomorpha* Bourd. & Galz. [RP], *Sebacina molybdea* McGuire on *Acer* [RFC], *Solenia fasciculata* Pers. [RFC], *Stereum fasciatum* Schw. [RP], *Stereum murrayi* (B. & C.) Burt [RFC] [RP], *Stereum rameale* Schw. [MF], *Stereum rufum* Fr. [MF], *Stereum sericeum* Schw. [MF], *Stropharia semiglobata* Fr. [MF], *Trametes subrosea* Weir. [RFC].

FUNGI IMPERFECTI: *Acrothecium apicale* (Berk. & Br.) Hoehn. on *Acer* [RFC], *Cephalothecium roseum* Cda. [MF], *Cercospora varia* Pk. on *Viburnum alnifolium* [RFC], *Cladosporium herbarum* (Pers.) Lk. [MF], *Cytospora leucostomoides* (Pers.) Sacc. [RP], *Dothiorella quercina* (Curt. & Ell.) Sacc. [RFC], *Glomerularia corni* Pk. [SMP], *Haplaria salicina* (Sacc.) Höhn. [RFC], *Leptostromella filicina* (B. & C.) Sacc. [RFC], *Libertella betulina* Desm. [RFC], *Phyllosticta acericola* C. & E. [MF], *Septoria rubi* West [RFC], *Sphaeronema acerinum* Pk. [MF], *Steganosporium acerinum* Peck. & Bull. [RP], *Steganosporium tuberculiforme* [MF], *Trichoderma viride* (Pers.) Harz. [MF], *Tubercularia vulgaris* Tode on *Fagus grandifolia* [RFC].

PHYCOMYCETES: *Synchytrium decipiens* Farl. [MF].—J. C. GILMAN.

COTONEASTER AS A HOST OF GYMNOSPORANGIUM CLAVIPES IN MANITOBA[1]

In June and July, 1949, pycnia and aecia of a plant rust were observed on the fruits of *Cotoneaster* bushes (labelled *Cotoneaster lucida*) growing in the garden of the Dominion Experimental Station, Morden, Manitoba. In the summer of 1950–51, rust was again observed on the fruits of these bushes, but no infections were found on the foliage.

Preliminary examination of the rust infections suggested that it was a species of *Gymnosporangium*. This was later confirmed by

[1] Contribution No. 1165 from the Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.

Mr. I. L. Conners, Division of Botany and Plant Pathology, Ottawa, who identified the rust as *Gymnosporangium clavipes* Cooke and Peck.

Cotoneaster species are known to harbour rusts of the genus *Gymnosporangium* in Europe and Asia, but this seems to be the first record of a rust parasitizing the fruits of *Cotoneaster* in North America.—A. M. BROWN, Dominion Laboratory of Plant Pathology, Winnipeg, Manitoba.

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Requests for single copies of the first number of the current volume, which included the articles "A decade of antibiotics in America," by Kenneth B. Raper, and "Molds, mutants and monographers," by Charles Thom, were so numerous that the edition seemed in danger of exhaustion. The two papers have been reissued together as MYCOLOGIA REPRINT No. 1, and can be secured from the undersigned at seventy-five cents a copy. It is intended that the reprint series will be added to in future years.—DONALD P. ROGERS.

REVIEW

INTRODUCTION TO MYCOLOGY, by J. A. MacDonald. 177 pp., 163 figs. Academic Press, N. Y., Butterworth's Scientific Publication, London, 1951. Price $3.00.

This is a short but thorough treatment of the main orders of the fungi utilizing selected life cycles as representatives. The arrangement of the chapters is as follows: 1—Introduction (3 p.); 2—General (13 p.); 3—Classification (1 p.); 4—Myxomycetae (4 p.); 5–9—Phycomycetae (36 p.); 10–14—Ascomycetae (44 p.); 15–18—Basidiomycetae (41 p.); 19—Deuteromycetae (4 p.); 20—Mycorrhiza (5 p.); 21—Lichenes (6 p.); Bibliography (5 p.).

The illustrations are line drawings, mostly original, but unfortunately so diagrammatic and lacking in details as to be of little value. Magnifications are not given for any figures; and there are no photographs. The text is concise and well written and American species as well as European species are included. Despite the disadvantages of the brevity of the text and the poor quality of the illustrations the book should prove to be useful in a short introductory course in mycology. The author is Lecturer in Botany, University of St. Andrews, Scotland.—S. M. PADY.

MANUSCRIPT

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